Food and Agriculture Organization
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WASAG | The Global Framework on Water Scarcity in Agriculture

STRATEGY REPORT

Compendium of community and indigenous strategies for **climate change adaptation**

FOCUS ON ADDRESSING WATER SCARCITY IN AGRICULTURE

COMPENDIUM OF COMMUNITY AND INDIGENOUS STRATEGIES FOR CLIMATE CHANGE ADAPTATION

FOCUS ON ADDRESSING WATER SCARCITY IN AGRICULTURE

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In 2013, the Regional Office for Africa of United Nations Food and Agriculture Organization (FAO) initiated field visits to rural communities in the Upper West Region of Ghana to collect and document their knowledge, practices and experiences in coping with water scarcity in agriculture. The initiative was justified by the need to understand how these communities survived, especially during the dry months of November to March. The Upper West Regional Office of the Environmental Protection Agency (EPA) of Ghana facilitated access to these communities.

Similar fieldwork took place the same year in Burkina Faso and Kenya, followed by a literature review, expanding the collection of experiences and practices to the entire African continent. This resulted in a draft 'Compendium of community and indigenous strategies for climate change adaptation in Africa' which was prepared by Patrick M. Bahal'okwibale, Prince Ansah, Ruhiza Boroto, Asher Nkegbe, Benjamin DeRidder and Cecilia Akita.

In 2017, the Agriculture Department of the FAO asked the Global Framework on Water Scarcity in Agriculture (WASAG) http://www.fao.org/land-water/overview/wasag/en/, a partnership managed by the Land and Water Division of FAO to facilitate the review and enrichment of the draft compendium through additional literature review to include case studies from other regions of the world, beyond Africa. The Natural Resources and Environment Unit of the Council for Scientific and Industrial Research (CSIR), South Africa was appointed to carry out this work. It included an online discussion which was facilitated by the Food Security and Nutrition (FSN) forum and which lasted three weeks (from 12 June to 07 July 2018). The summary of the online discussion is available at http://www.fao.org/3/CA2109EN/ca2109en.pdf.

The authors would therefore like to thank participants from 29 countries who shared 45 contributions over the three weeks of discussion on the FSN forum which was moderated by Jean-Marc Mwenge Kahinda of the CSIR and Patrick Bahal'okwibale of the FAO.

The document was prepared by the Council for Scientific and Industrial Research under the lead of Jean-Marc Mwenge Kahinda under the overall supervision and technical guidance of Ruhiza Boroto of the FAO, in close collaboration with Patrick M. Bahal'okwibale.

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ABBREVIATIONS AND ACRONYMS

AEZs	Agro-ecological zones
BC	Before Christ
CK	Community Knowledge
CSIR	Council for Scientific and Indusdrial Research (South Africa)
FAO	Food and Agriculture Organization of the United Nations
GAEZ	global agro-ecological zones
IIASA	International Institute for Applied Systems Analysis
IPCC	Intergovernmental Panel on Climate Change
IK	Indigenous Knowledge
iRWH	in-situ RWH
RWH	Rainwater harvesting
TEK	Traditional Ecological Knowledge
US	United States of America
WASAG	Global Framework on Water Scarcity in Agriculture
WH	water harvesting
WRI	World Resources Institute
xRWH	ex-situ RWH

SUMMARY

Climate change is a major challenge for life on Earth. It is mainly manifested through modifications of average temperature, rainfall intensity and patterns, winds and solar radiation. These modifications significantly affect basic resources, such as land and water resources. Populations at disproportionately higher risk of adverse consequences with global warming of 1.5°C and beyond include disadvantaged and vulnerable populations, some indigenous peoples, and local communities dependent on agricultural or coastal livelihoods (IPCC, 2018). Therefore, adaptation measures are recommended in order to cope with climate change. Indigenous peoples have developed practices for climate change adaptation, based on their long-term experience with adverse climatic effects. There was thus a need to identify such practices as they could be effectively mainstreamed in community-based adaptation programmes. This report makes an inventory of indigenous and community adaptation practices across the world. The inventory was mainly done through literature review, field work and meetings with selected organisations.

The case studies documented are categorized in six technologies and practices themes, including: (1) Weather forecasting and early warning systems; (2) Grazing and Livestock management; (3) Soil and Water Management (including cross slope barriers); (4) Water harvesting (and storage practices); (5) Forest Management (as a coping strategy to water scarcity), and; (6) Integrated wetlands and fisheries management. These were then related to the corresponding main agro-ecological zones (AEZ). The AEZ approach was considered as an entry-point to adopting or adapting an existing indigenous strategy to similar areas.

Challenges that threaten the effectiveness of indigenous and community adaption strategies were identified. These challenges include climate change itself (which is affecting the indicators and resources used by communities), human and livestock population growth (which is increasing pressure on natural resources beyond their resilience thresholds), current institutional and political settings (which limit migrants' movements and delimits pieces of usable land per household), cultural considerations of communities (such as taboos and spiritual beliefs), and the lack of knowledge transfer to younger communities.

Indigenous knowledge provides a crucial foundation for community-based adaptation strategies that sustain the resilience of social-ecological systems at the interconnected local, regional and global scales. In spite of challenges and knowledge gaps, these strategies have the potential of being strengthened through the adoption and adaptation of introduced technology from other communities or modern science. Attention to these strategies is already being paid by several donor-funded organisations, although in an uncoordinated manner. Consequently, this compendium is a first step at providing a comprehensive listing of indigenous strategies for climate change adaptation focussing at addressing water scarcity in agriculture.

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INTRODUCTION

There are between 300 and 500 million self-identified indigenous peoples across some 90 countries worldwide, representing around 5 percent of the world's population (Chao, 2012). Traditional indigenous territories encompass up to 22 per cent of the world's land surface from small islands, tropical forests, high-altitude zones, coasts, desert margins and the circumpolar Arctic. These territories coincide with areas that hold one-fourth of the planet's biodiversity (WRI *et al*., 2005). Thus, most biodiversity hot spots in the world are in places indwelled by indigenous people. This clearly indicates that indigenous people have been able to protect their biodiversity with their traditional knowledge, wisdom and practices (Martemjen, 2017).

Indigenous peoples are the ones affected by climate change the most, although they have hardly participated in the activities that are its primary cause. This is largely a result of their historic reliance on local biological diversity, ecosystem services and cultural landscapes as a source of their sustenance, wellbeing and resilience.

The identity of indigenous people is intricately linked with their lands, which are mostly sited at the social-ecological margins of human habitation. At these margins of the dominant society's encroachment on global biocultural heritage, the consequences of climate change include effects on agriculture, pastoralism, fishing, hunting and gathering, and other traditional activities, including access to water. Fortunately, indigenous people possess a unique collective knowledge of land, sky and sea that makes them excellent observers and interpreters of change in the environment.

Through knowledge accumulated over generations of living in a particular environment, indigenous people have developed a unique form of skills to respond to environmental challenges including floods, droughts, disease and pest infestations, and their attendant effects (Egeru, 2012), therefore, to reduce their vulnerability to climate variability (Kumar, 2014). Unfortunately, this knowledge is seldom taken into consideration in the design and adaptation of modern mitigation and adaptation strategies because it is hardly documented and even less recognized. Indigenous knowledge systems have survived for many centuries without preservation as written text. It is necessary to revitalize and support indigenous knowledge systems, to address current challenges such as climate change. Indigenous knowledge is now recognized as a critical resource that must be promoted to support livelihoods and food security, often under variable or changing climatic conditions. This document seeks to develop a compendium of community and indigenous strategies for climate change adaptation.

IDENTIFYING CASE STUDIES

There are several case studies available in the literature. However, most of them are barely narrated and the geographic location of the communities vaguely identified. Therefore, the following criteria are used to qualify a strategy as a case study to include in this compendium. The criteria are as follow:

1. They include a local/indigenous/community knowledge
2. The knowledge is linked directly to the relationship people have with their natural environment
3. It is part of a body of knowledge and beliefs shared by a group of people (resource users) over time
4. Mainly transmitted through cultural transmission (often orally)
5. Mainly qualitative as it is difficult to measure
6. Does not have to be proven by science as it is may be based on empirical observation rather than an accumulation of fact – thus makes sense within the context of that particular place, culture or tradition.
7. The knowledge is documented in a peer-reviewed publication, grey literature or a website.

THEMES

Four themes are presented:

i. The Technologies and Practices theme is illustrated using georeferenced narrative case studies;
ii. The Semantics and the Governance themes are narratives of the insight gained from existing literature.
iii. The Youth attitude, taboos, alternative livelihoods and other practices theme is unpacked through narrative case studies that are not georeferenced.

Theme 1: Technologies and Practices

Objective: *to identify and assess the sustainability and replicability/ upscaling of technologies and practices for coping with water scarcity in agriculture in the context of climate change.*

Topic 1.1. Weather forecasting and early warning systems
Topic 1.2. Grazing and Livestock management
Topic 1.3. Soil and Water Management (including cross slope barriers)
Topic 1.4. Water harvesting (and storage practices)
Topic 1.5. Forest Management (as a coping strategy to water scarcity)
Topic 1.6. Integrated wetlands and fisheries management

Theme 2: Semantics

Objective: *to explore the appropriate terminology for the technologies and practices under discussion.*

Topic 2.1. Distinguishing between local and indigenous knowledge
Topic 2.2. Clarifying the use of TEK as alternative

Theme 3: Governance

Objective: *to identify factors influencing an enabling environment for the adoption of the practices and make recommendations.*

Topic 3.1. Land Tenure Systems

Theme 4: Youth attitude, taboos, alternative livelihoods and other practices

Objective: *to identify other factors affecting the sustainability of the technologies and practices.*

Topic 4.1. The Youth's attitude towards technologies and practices
Topic 4.2. Taboo, cultural, religious and spiritual beliefs
Topic 4.3. Other practices

STRUCTURE OF THE CASE STUDIES

To have a consistent narration of the case studies, the structure below was adopted (Table 1).

Table 1. The proposed structure of the case studies

THEME	Technologies and Practices
Topic	Weather forecasting and early warning systems
WHO	Aboriginal communities such as the Nyungar
WHERE	in southern Western Australia
WHAT	Identify six seasons (Smith and Kalotas, 1985) based on the interaction between meteorological patterns (direction of prevailing wind and rainfall intensity), the flora (flowering and fruit ripening time) and the fauna (animal abundance and fatness).
VALUE/MEANING	The seasons which are the main determinants of the timing and movement of the communities, assist in the conservation of traditional hunting, fishing and gathering activities. Such activities may enable this indigenous community to enhance their adaptive capacity in the face of a changing climate
KNOWLEDGE	Some aboriginal Australians still rely on a diet of fruits and vegetables, nuts and grains, meats and fish, oils and fats sourced from the bush, the land, waterways and the seas. This knowledge has been orally transmitted through generations.
ADDED INFORMATION	This knowledge has been orally transmitted through generations, specifically for food gatherings such as nuts and grains from mother to daughter, and hunting and fishing techniques from father to son as part of coming of age rites of passage for boys.

The case studies are therefore currently presented per Themes and Topics as indicated below:

Technologies and Practices

Weather forecasting and early warning systems

Aboriginal communities such as the Nyungar, in southern Western Australia, identify six seasons (Smith and Kalotas, 1985) based on the interaction between meteorological patterns (direction of prevailing wind and rainfall intensity), the flora (flowering and fruit ripening time) and the fauna (animal abundance and fatness).

The seasons which are the main determinants of the timing and movement of the communities, assist in the conservation of traditional hunting, fishing and gathering activities. Such activities may enable this indigenous community to enhance their adaptive capacity in the face of a changing climate.

Some aboriginal Australians still rely on a diet of fruits and vegetables, nuts and grains, meats and fish, oils and fats sourced from the bush, the land, waterways and the seas. This knowledge has been orally transmitted through generations, specifically for food gatherings such as nuts and grains from mother to daughter, and hunting and fishing techniques from father to son as part of coming of age rites of passage for boys.

As previously alluded, it is very difficult to find all those elements in literature. Thus, for most case studies presented, only a few of these descriptors are available.

Case studies are numbered per theme, topic and continent. For example the case study numbered [1.2.3a] should be interpreted as follows:

- The number '1' denotes that the case study is under Theme 1: Technologies and Practices. There are four themes but only the case studies under theme 1 are numbered.
- The number '2' denotes that the case study is under the Grazing and Livestock management topic. There are 6 topics under theme 1: 1 = Weather forecasting and early warning systems; 2 = Grazing and Livestock management; 3 = Soil and Water Management (including cross slope barriers); 4 = Water harvesting (and storage practices); 5 = Forest Management (as a coping strategy to water scarcity); 6 = Integrated wetlands and fisheries management.
- The number '3' denotes that the case study is located in Asia. The five continents are coded from 1 to 5 as follow: 1 = Africa, 2 = America, 3 = Asia, 4 = Europe and 5 = Oceania;
- The letter 'a' denotes the case study number per se. Those are numbered alphabetically: a, b, c, ..., z, aa, ab, ac, ... ,az, ba, bb, ...zz, aaa, aab ... etc.

METHODOLOGICAL APPROACH

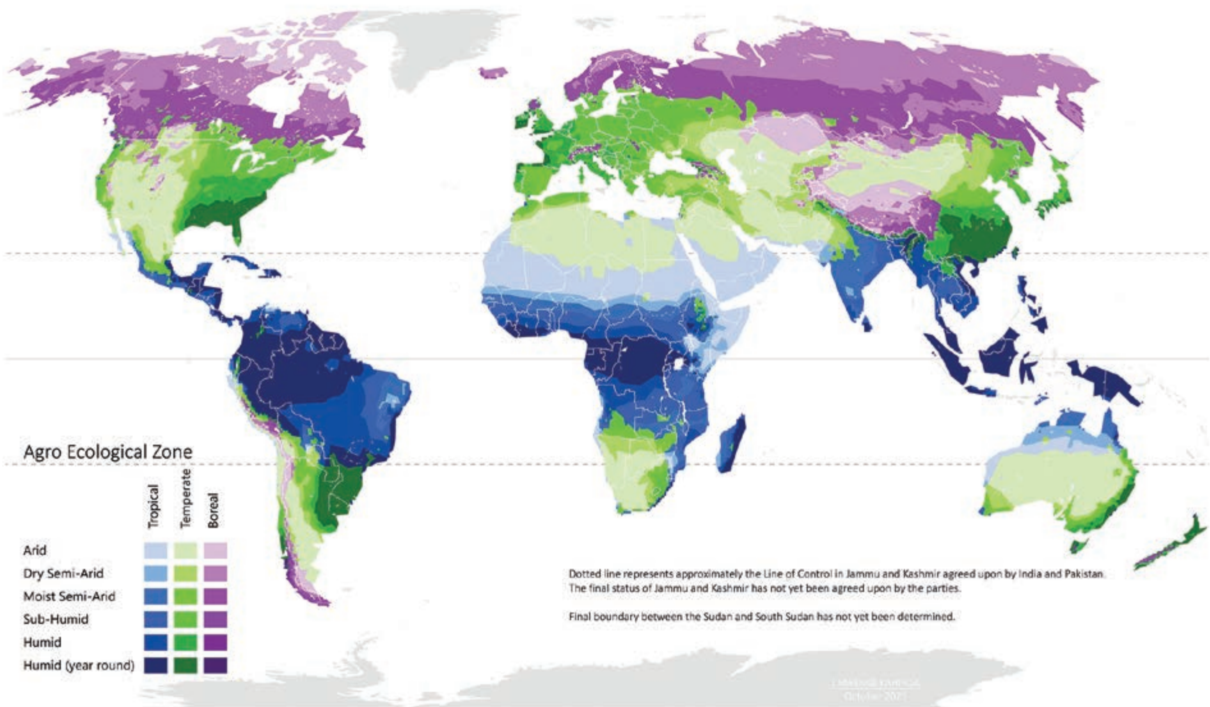
A literature review was carried out in order to identify cases of indigenous knowledge and practices for climate change adaptation across the Globe. Relevant information in this regard was thus collected.

Case studies narrated in this document were obtained from secondary data primarily sourced in peer-reviewed literature. Those case studies will be categorized and presented in relation to global agro-ecological zones (GAEZ, Figure 1).

AEZ are preferred because they best describe the similarity of conditions between areas under rainfed agriculture. Two approaches were used to associate agro-ecological conditions with the identified adaptation strategies:

- Adaptation strategies are categorized according to their application such as weather forecasting and early warning systems, etc.;
- In most cases, information on agro-ecological conditions of the case study is lacking. Thus, the GAEZ shapefile (FAO and IIASA, 2010) is overlaid with the case studies' locations to identify their agro-ecological conditions.

Figure 1. Distribution of agro-ecological zones (AEZs 1-18). Shades of blue, green and purple represent tropical, temperate, and boreal AEZs, respectively



Source: World Bank, 2021 & Plevin *et al.*, 2014, modified to comply with UN Geospatial. 2021. *Map of the World*. Washington, DC, UN.

THEME 1: TECHNOLOGIES AND PRACTICES

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Objective: *to identify and assess the sustainability and replicability/upscaling of technologies and practices for coping with water scarcity in agriculture in the context of climate change.*

TOPIC 1.1. WEATHER FORECASTING AND EARLY WARNING SYSTEMS

Weather forecasting and early warning system in Africa

A number of East African communities have adopted various indigenous weather forecasting methods over the years. Most of the methods adopted have either been weather-related forecastings such as observing the colour of the sky and or the use of natural indicators such as observing animals, plants or insects. In Uganda (Hoima [1.1.1a], Rakai [1.1.1b] and Bahima [1.1.1c], the visibility of the nimbostratus and cumulonimbus clouds indicates a high possibility of rainfall.

In Ethiopia, Borana [1.1.1d] and Afar [1.1.1e]), the aspect of "white feather-like column (vertically standing) cloud in the sky is a signal that rain is about to occur" (CCAFS, 2017). Generally, a sky dominantly covered with light cloud indicates a drought season.

Pastoralists from northern Kenya [1.1.1f] (Ariaal, Boran, Chamus, Gabra and Rendille tribe) and southern Ethiopia (Guji tribe) [1.1.1s] observe the speed of wind, movement of stars, the position of the moon and lightning to predict the next rain season (Luseno *et al*., 2003). Others interpret dreams or even the patterns in which their pair of shoes have fallen on after it has been repeatedly thrown. More so, observing animal (livestock, wildlife or local flora) behaviour or reading intestines of slaughtered animals such as goats, sheep, and cattle, projects the period of a drought, the severity, affected areas, and disease outbreak (Luseno *et al*., 2003).

In Lushoto [1.1.1g], Tanzania, the start of short rains is identified by the existence of "large flocks of swallows and swans, roaming from the South to the North during the months of September to November" (Mahoo *et al*., 2015).

Evidently, indigenous knowledge plays a significant role in enabling local communities to make sense of environmental change, mostly at a local level (microclimate). With environmental change taking place, more communities are adapting to weather changes through indigenous weather forecasting techniques. These techniques have been mainly aimed at predicting seasonal climate change, for instance, the onset of rainfall, which areas will receive more rainfall, and the end of rainfall. These climatic patterns have been important for pastoralists as they are often at "finer" Spatio-temporal resolution compared to modern climate forecasts (Luseno *et al*., 2003). Thus, farmers and communities persistently depend on their own local forecasting techniques as they are grounded in their own experiences. These indigenous forecasting methods, therefore, allow communities to adapt in the face of a changing climate.

In Bonam village [1.1.1h], Central Plateau of Burkina Faso, climate indicators used by farmers to forecast incoming rainfall season becomes accessible for examination at various times of the year, starting instantly after the harvest period until the beginning of a new rainy season. The farmers depend mostly on observing food production trees at the start of the rainfall season and temperatures during the dry season. The observation of winds, sky, plants, animals and the behaviour of birds and insects are also a forecasting method regularly used by farmers in Burkina Faso [1.1.1i] (Roncoli *et al*., 2002). These predictions estimate the onset date, intensity and the duration of the cold and dry season. Older male farmers tend to be more knowledgeable than younger men or women farmers. However, knowledge differs significantly among elders. More so, spiritualists, who have inherited powers or received skills by the honour of initiation or selection by the spirits, have knowledge that is not available to all (*ibid*).

In the Makueni district [1.1.1j], southeastern parts of Kenya, the "weakness of poultry, cattle and human beings and the abundance of honey in the hives notifies a drought during the next season (Speranza *et al*.,2010). Also, the appearance of rare birds or insects, nocturnal noise of crickets, quiet frogs and the presence of nimbus clouds in the day and their absence at night indicates a drought period. These observations allow agro-pastoralists to change their tradition if they have previous understanding of an approaching drought or flood. As such, their indigenous forecasting techniques allow them to cope and respond to climatic changes while alleviating its impacts.

Indigenous knowledge has been and continues to be, used for climate monitoring. The study conducted by Speranza *et al*., (2010), in southeastern Kenya [1.1.1f], demonstrates the richness of indigenous knowledge and the diversity of indigenous knowledge based signals for monitoring climate variability and change. As such, various indicators from flora, weaver birds, weather variables, astrology (constellation of stars), to the environment (shadow of hills), contribute towards awareness (*ibid*). This is an indication of knowledge that has been passed down from one generation to another and helps communities prepare in time, for environmental change.

In South-Omo Ethiopia (Dassenech [1.1.1k] and Nyangatom Wereda [1.1.1l]), when the Omo River does not overflow to the surrounding flats, a drought and food shortage period awaits (Gebresenbet and Kefale, 2012). However, if the river overflows a great deal, houses, people and livestock could possibly be swept away. Indigenous early warning methods rely quite a bit on predictions and observations of animal behaviour as it helps many communities prepare for the rise in water by projecting incoming rains and their intensity. These projections help communities make decisions, for example, people will have no choice but to move from the Omo River if severe flooding is expected (*ibid*). In such instances, the "elderly reach a decision based on predictions made by observing stars, winds and cloud patterns, behaviour of specific wild animals or the flowering of some plants which will be passed to the youth of the group who will then move the herd to a safe place" (Gebresenbet and Kefale, 2012). This early warning system gives the community enough time to move into either safer areas when a flood is predicted or wetter areas in times of drought. Notably, elders with the knowledge or skill to predict weather changes are respected by the whole community.

Pastoralists and agro-pastoralists in the south [1.1.1m] and east [1.1.1n] Ethiopia are living in arid and semi-arid rangelands (Enyew and Hutjis, 2015). As a result, a movement is a key strategy for pastoralists, particularly when dealing with sudden rainfall, livestock diseases and sustainable use of sparse natural resources. Pastoralists in Ethiopia experience a number of challenges that jeopardise

the sustainability of their traditional practices. Such as trends indicating climate change, such as increasingly recurrent drought, floods, erratic rainfall patterns, and high temperatures are adding significantly to these stresses (*ibid*).

In the Teso sub-region, Eastern Uganda [1.1.1o], the growth of new leaves in January and February indicates the onset of a rain period. This indicates that gardens should be tilled, while others sow millet in the soil, awaiting approaching wet season in March (Egeru, 2012). In the Ngora district [1.1.1p]), Uganda, rain season was predicted by winds blowing from East to West and the redness of clouds in the East was a prediction of hailstones. The Rakai District [1.1.1b] in southwestern Uganda, relies on climatic, flora and fauna indicators to predict the onset of rainy season. Warmer temperatures at night time, changes in wind direction, the flowering of coffee trees, certain phases of the moon, the appearance of whirlwinds that lift dust and leaves and the arrival of the Abyssinian hornbill are indicators of a good rain season (Orlove *et al*., 2010).

Similarly, in the Upper West region of Ghana [1.1.1q], the flowering and fruiting of the baobab, shea, and the dawadawa trees is an indication of a favourable rainfall season. The ripening of the fruits especially the shea fruit is also an indication of a good rain season (Gyampoh *et al*., 2011). In some local communities such as Bankpama [1.1.1r] (Upper West), Pwalugu [1.1.1 s] and Talensi [1.1.1t] (Upper East) of Ghana, the visibility of frogs or croaking frogs around March, indicates a good wet season.

In the Jensue community of Western region of Ghana [1.1.1u], the formation of a rainbow in the east at dawn indicate that they will receive below average rainfall this season (Gyampoh *et al*., 2011). Furthermore, the movement of wind and dark clouds and the appearance of the sun in the morning indicate the pattern of rainfall in the Aowin-Suaman District [1.1.1u] in the Western region of Ghana. The Old Yakase community of in Ghana [1.1.1v], predict a strong rainy season through the observation of thunder and lightning in March, prior to the rainy season. Other communities observe the shedding and sprouting of leaves on trees in particular months of the year, as an indication of the beginning and end of seasons (Gyampoh and Asante, 2011).

The appearance and disappearance of some migratory birds are natural indicators of the nature of the farming season. For the Jensue community

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of Ghana [1.1.1u], the appearance of the "Brobbey" (larger than the crow, blue-black in colour and has a strand of feathers on its head like that of the comb of a cock), announces the beginning of the raining season. The bird is said to be "god's announcer" because it comes every year to announce the beginning of the rainy season (Gyampoh *et al*., 2011). Millipedes and centipedes seen climbing to higher grounds at the start of the rains indicate that there is going to be flooding in the community (*ibid*).

The examples above indicate the highly social nature of knowledge. Communities have developed different means to exchange information that they are unable to retrieve; assisting them to acquire an awareness of the occurrence and progress of the rains (Orlove *et al*. 2010). Furthermore, all the elements of this indigenous knowledge; the historical patterns, the indications, the weather examinations, and the regional information, are broadly attainable and broadly shared. Elders are served with respect in conversations about the weather as in many other settings, and their knowledge of individual experience is regarded to be of great worth (Orlove *et al*. 2010). Notably, although indigenous forecasting techniques have been passed down from generation to generation through "oral history" and local expertise, there remains a wide inter-generational gap between its custodians and the young people (Mahoo *et al*., 2015).

For the Dzelukope community of Ghana [1.1.1w], hot weather from January to April is an indication of a good rainy year. The degree of hotness of the ground an indicator of a very heavy rainy season (Kpadonou *et al*., 2012).

Farmers in the South-Western Free State [1.1.1x] often experience climate and weather-related disasters, such as droughts, floods, untimely frost events, severe and persistent winds that intensify dangerous wildfires, outbreak of diseases and pests that severely affect their farm output, as well as overgrazing that poses dangers of soil erosion and land degradation (Zuma-Netshiukhwi *et al*., 2013). These farmers rely on weather and climate-linked indicators to predict immediate seasonal rains and droughts, including observing animal and plant behaviour, as well as observing other climatic elements. For instance, they use budding of acacia Karoo and sprouting of *Aloe ferox* in the mountains as an indication of coming good rains. In September, the flowering of wild lilies in the veld and dropping of fig tree leaves (*Ficus carica*) is an indication that summer is approaching (*ibid*). Also, immature fruits drying on the trees and dropping between September and October is an indication of drought. These traditional farmers use these indicators as a guide for agricultural activities to be undertaken.

Similarly, farmers in the Karoo (Beaufort West [1.1.1y], Prince Albert [1.1.1z] and Oudtshoorn region [1.1.1aa]), Ganyesa Village [1.1.1ab] of North West province (Tlhompho, 2014; Ncube and Largedian, 2015) observe the fauna to predict weather conditions. For instance, calves running and playing in the field in the Karoo (Beaufort West, Prince Albert, and Oudtshoorn region and in the South Western Free State is an indication that rain is coming in few days (Zuma-Netshiukhwi *et al*., 2013; Ncube and Largedian, 2015). Moreover, in the Karoo and in the South Western Free-State, black ants (*laisius niger*) collecting and storing food, the presence of red ants and a rapid increase in size of moist anthills, the appearance of reptiles like snakes moving up and down in the mountains between August and September, appearance of red dominated rainbow colours between June and July as well as increased libido in goats, predicts good rains. Similarly, in Mogalakwena community in Limpopo Province [1.1.1ac] if the cattle herd hesitates to go to the veld for grazing, within a few hours there will be rains (Rankoana, 2016). Consequently, farmers start preparing for a growing season. Furthermore, the grunting of pigs indicates low humidity and an increase in temperature in the South-Western Free state. The presence of tortoise (*chersina, angulate*) is an indication of a thunderstorm (Ncube and Largedian 2015).

Mogalakwena community of Limpopo Province [1.1.1ad], South Africa the Senegal plant species produce yellow flowers at the start of September, which according to the local people indicate the start of a good season with approaching rainfall nonetheless if the flowers are deep-yellow, pale flowers thus predict limited rainfall (Rankoana, 2016). Additionally, the appearance of *tsie* (edible insects) in greater numbers in spring in that community signifies shortage of rain in the next season.

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Weather forecasting and early warning system in America

In Incas [1.1.2a], Peru, observations of the constellations, phases of the moon as well as the salinity of raindrops are used to determine weather and climate (Eakin, 1999).

In Tlaxcala [1.1.2b], Mexico, animal behaviour, sky appearance, and astronomical observations are used to forecast weather. Ants flying away of underground nests are used to predict wind direction; while, the height of swallows' flock is used to predict rain events. Drop in temperature and thin clouds are indicators of frosts; while, high black thick/puffy clouds with white peaks are indicators of hail storms. Moon phases are also used for rain and dry day predictions (Eakin, 1999).

In Tlaxcala [1.1.2b] Mexico *El Galván* (Mexican equivalent of the farmer's almanac used in the United States, except that it is based in the liturgy of the Catholic Church) and Cabãnuelas (relatively informal system of environmental observations that is used to anticipate general climate conditions for a whole year) are methods used by farmers to forecast weather (Eakin, 1999). *El Galván* was founded in 1826 by Don Mariano Galván Rivera and is now published annually by a press in Mexico City. While; the origins of the *Cabãnuelas* system possibly could be traced to the conquistadors as the system seems to have little to do with the climatic patterns of particular localities. These practices, which are passed on to present generations of producers are increasingly abandoned. The new generation perceives them as complex, time-consuming (*Cabãnuelas*) and expensive (*El Galván*). Furthermore, they are seen as less reliable because of the increasing climatic variability.

Indigenous knowledge continuously plays a significant part in the manner communities interconnect with their climate in many countries, particularly in Bolivia [1.1.2c]. It contributes to weather forecasting at the community level, and to the protection of essential ecosystem operations that assist to protect communities against climate change impacts. However, the increasing occurrence of extreme weather events and disasters is taking a toll (DeAngelis, 2013). Over generations of observing their environment, Bolivia's indigenous people have adjusted a distinctive body of knowledge that assists them to adjust to the consequence of climate change throughout weather forecasts and survival strategies (Kronik and Verner, 2010). The Chipaya [1.1.2c] people, for instance, observe the wind, clouds, frosts and other indications to forecast the weather and enhance agricultural practices (DeAngelis, 2013).

Weather forecasting and early warning system in Asia

Asian communities are tremendously vulnerable to natural disasters such as droughts and floods. Archipelago [1.1.3a] and small Island states of Southeast Asia are specifically exposed to the effects of hydro-meteorological hazards (Hawasaki *et al*. 2014). Different communities use diverse mechanisms and indicators to predict weather conditions. Before the use of modern scientific methods for weather forecasting and climate prediction, farming and other livelihood pursuits were sustained by traditional knowledge (Rautela and Karki, 2015). Traditional local communities continue to rely heavily on their indigenous knowledge systems to adapt to climate variability.

Villages located in the Johar, Byans, Bhagirathi and Niti valleys of Higher Himalaya in Uttarakhand [1.1.3b] (India), forecast weather using bioindicators and physical factors such as wind direction, time of the year, the colour of sky and position of stars (Rautela and Karki, 2015). By closely observing the behavioural change of their natural environment, they predict the present and future events like weather (Mishra, 1998).

In the Houldari village of South Andaman district [1.1.3c] (Andaman and Nicobar Islands of India), the aspect of specific birds, the mating of specific animals and the flowering of specific plants are all perceived as major signals of change regarding to timing and seasonality of natural phenomena that are well known in traditional knowledge systems (Sethi *et al*., 2011). The fruiting of peaches (*Prunus persica*), apricots (*Prunus armeniaca*), figs (*Ficus sp*.) or the budding of certain trees in the farms is an indication of the onset of spring; while, the emergence and growth of new leaves indicates that the temperature is increasing and the winter season is drawing to an end (Rautela and Karki 2015). If a rainbow arises from the east it is believed that there could be a drought however if it appears in the west there will most likely be good rains (Sethi *et al*., 2011). The luxuriant growth of forest vegetation indicates an above average rainfall season.t year. Snails climbing certain trees, earthworm crawling, ants shifting to safer places and insects flying around, presage cyclonic weather followed by heavy rain (Sethi *et al*. 2011). Redness in the sky after sunset stipulates cyclonic storms/ disaster within seven days.

In Rajasthan [1.1.3d] (India), the appearance of butterflies indicate early rainfall onset and gives an indication of a good season (Pareert and Trivedi, 2011).

In villages of the Aizawl [1.1.3e] (Tanhril, Muthi and Seling), Champhai [1.1.3f] (Champai Aizwal and Hnahlan) and Saiha [1.1.3g] (Saiha, Teiva and

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Tuipang) districts, state of Mizoram (Northeast India), the experiences and knowledge passed through generations continue to play a vital role to the sustainability of the communities (Chinlampiamga, 2011). These communities use different indicators such as birds, insects, fish, plants, and clouds to predict weather and seasonal conditions. When male bamboo partridge roar frequently during spring and summer in the morning after sunrise, rains are expected. On the contrary, when it rains in the morning, the roaring of the bamboo partridge indicates that the rains will stop. Furthermore, when there are several ants moving along a path carrying their food items with them, heavy rain is expected on the same day (Chinlampiamga, 2011).

The Intertropical Convergence Zone increases the rain intensity and thunderstorm in the Philippines [1.1.3h], triggering flooding and other natural disasters to which, many communities are extremely vulnerable (Hawasaki *et al*., 2014). For centuries, these communities have developed mechanisms to survive natural hazards. With climate change vulnerabilities *Bayanihan* (an action done by a group of people to help those in need) is used by a number of communities in the Philippines in times of emergencies and disaster (Hawasaki *et al*., 2014). Indigenous knowledge has also played a key role in climate change adaptation strategies of these communities.

The Ilocos Norte [1.1.3h] community, in the Philippines, relies on their traditional knowledge to predict short, medium and long-term weather changes. To forecast weather condition, atmospheric and astronomic phenomena, plant phenology and animal behaviour are observed. The farmers predict rainfall by observing clouds; when clouds near the sun look reddish at dawn and when it is cloudy in the east or the west, it will rain. Furthermore, rain is expected to fall within a day or two when the moon and stars are seen dim and a rainbow appears in the morning (Galacgac and Balisacan, 2009). This knowledge enables farmers to timely plants suitable crops and gives them time to prepare for the occurrence of harsh weather conditions such as thunderstorms, floods, typhoons, and even droughts (Galacgac and Balisacan, 2009).

Traditional phonological indicators assist people in Tripura [1.1.3i] (Northeast of India) in planning for agroforestry and disaster prevention. Thus, the phenology of the night-flowering jasmine (*nyctanthes arbor-tristis L.*) is used to predict the beginning of heavy rainfall events (Archarya, 2010).

The indigenous Pagu [1.1.3j] and Gura [1.1.3k] communities in Indonesia have their individual methods of forecasting imminent dangers (Carling and Sherpa, 2015). The unforeseen low tide with a strong smell of salt from the sea, the development of bubbles in large quantities accompanied by a loud roar from the sea and high-black and long waves, indicate upcoming danger in the island. Whoever sees these signs, will hit the *Toleng-toleng* (a communication tool made from bamboo/iron and knocking) to alert others of the upcoming Tsunami. The same communities use the signs of nature and animal behaviours to certify the changes in the season. This is called *"nanaku"*, which is the knowledge to forecast an event based on their past experiences. Consequently, the coming of the Kurihara birds (local name) to the mangrove area on the islands of Kumo, Tagala, and Kakara, is an indication of the change of wind direction (wind is blowing from the south) and the start of the rainy season. The coming of the Maleo bird (*Macrocephalon maleo*) indicates the change of the sea water level. The typical voice of this bird signals notable changes in the sea level. Also, the migration of *Luo-Luo* birds (local name) to the mangrove on the island of Kumo and Kakara indicates the abundance of fish in the sea. These birds come to the islands to find food (fish). People frequently use these signs to obtain fish species that will be captured in the sea. Similarly, *"Mangele"* is the knowledge to notice the position of clouds above Mount Dukono, which is an active volcano. According to their reading, if the clouds are straight, thick and cover the top of the mountain, it is a signal that there will be big waves, strong winds, and very strong currents. During these conditions, people are advised not to fish.

For the Tangkhul community [1.1.3l] (North East India), the emergence of giant earthworms after a dry period is an indication of rain (Carling and Sherpa, 2015). The communities forecast drought by the behaviour of animals that live in burrows such as the erratic emergence of the Pangolin towards the end of winter or start of spring as an indication of drought or late monsoon, and the content of moisture level in their burrow as a sign of good rain. The annual climatic forecast of the community is done by observing the weather pattern during the seed sowing festival, which falls towards the end of January. Their forecast is connected to the average

weather conditions like the optimal rain that will occur in good harvest, drought or changes of rain pattern that will interrupt the plantation period or flowering period of their crops.

The Karen communities [1.1.3m] (Thailand) predict earthquakes and floods by observing the behaviour of cats and dogs (Carling and Sherpa, 2015). If cats run in an unusual way, there will be an earthquake. Indigenous people living close to the river use the behaviour of dogs (running in total chaos or walking in an unusual way) as an indication that there is a potential flood is coming.

In Rapu-Rapu [1.1.3n] (Philippines) and Aceh [1.1.3o] (Indonesia), a foul odour emitted from the sea indicated the coming of a storm or typhoon. In Perez [1.1.3p] and Rapu-Rapu [1.1.3n], Philippines, various animals are used to predict hazards: rays jumping consecutively in the sea in summer, the fast movement of sea snakes, and hermit crabs going inland or climbing up trees all signal storms or typhoons (Hawasaki *et al*., 2014). These observations are also signals of other hazards such as landslides and flooding. In Rapu-Rapu island [1.1.3n], Philippians when branches of tree such as (gmelina ta lisay, pili, and marukbarok, tamarind santol, narra) and banana leaves fall on the ground, are an indication of heavy rains, storm surges or strong winds in two days (Hawasaki *et al*., 2014).

Weather forecasting and early warning system in Europe

In Doñana [1.1.4a], southwestern Spain, traditional weather predictions included inspections of wind strength and direction, cloud and moon shapes, and bird migrations as well as animal behaviour. The dominance of winds from the southwest signalled rain. Shepherds on the other hand use direction of horns of the moon at fixed times of the autumn and winter to predict rain, this is a communal belief in traditional Mediterranean societies (Gómez-Baggethun *et al*., 2010).

For long-term weather forecasts, local people used *Las cabañuelas*, a traditional form of weather prediction practised throughout the Hispanic diaspora. The system is based on measurement and observation made during the month of January however, in some areas the month of August is used also as a period of tracking shift in weather conditions. *Cabañuelas* is also practised throughout South America, including the Caribbean, and even in parts of Africa that were previously territories of Spain. In Spain [1.1.4b] *Las cabañuelas* are organized in the *Asociación Cultural Española de cabañuelas y Astrometereología* and every year, they report the weather for the coming twelve months. (Eakin, 1999; Gómez-Baggethun *et al*., 2010; Herrera-Sobek, 2012).

Herders of the Conquense Royal Drove Road in Mediterranean Spain [1.1.4c] observe animal behaviour throughout transhumance. Transhumance is the seasonal migration of livestock between summer pastures (highlands, usually northerly latitudes) and winter pastures (lowlands, southerly latitudes) (Ruiz & Ruiz, 1986; Baena & Casas, 2010). Transhumance necessitates deep knowledge and understanding of the location and accessibility of natural resources, ecosystem types, and responses to disturbances such as diseases, and formal and informal institutions that regulate transhumance. The wandering of wild species indicates transitorily rain; while downwards toads walking indicate that it will not rain the following days (Oteros-Rozas *et al*., 2013).

The use of animals to predict weather has a long history in the European continent. For centuries, Europeans observed hibernating animals, such as bears, badgers, and hedgehogs, for signs of spring. Farmers of northern Europe observe the emergence of hibernators, such as the hedgehog or badger, to signal the coming of spring in order to start spring planting.

Weather forecasting and early warning system in Oceania

In Oceania [1.1.5a] there are some similarities in methodologies used to predict weather conditions such as observation of seasonal change, identification of cloud formations, changes in animal and plant behaviour as well as other natural environmental changes.

Over centuries, indigenous communities of Oceania [1.1.5a] developed an appreciation of their local ecosystems and its climatic variation. They still rely on and live closely connected to their natural environment. Indigenous knowledge is therefore highly valued by these communities, as it is used

to inform decisions in planting, fishing and hunting as well as other seasonal dependent events such as (Green *et al*. 2010).

The Baada, commonly called the *Bardi*, an indigenous community of south-west Kimberley [1.1.5b] (Western Australia), has a concept of seasonality more complex than that of a two-fold Wet-Dry pattern (Green *et al*., 2010). They recognize six seasons, distinguished mainly by wind and rainfall direction and intensity, ripening of fruits, and appearance, disappearance and 'fatness' of fish and animals. *Mangal* is the Wet, the rains, the monsoon season, characterized by strong winds and storms from the ocean (*ungulungul*) and whirlwinds (*adjibangur*). People shift away from the coast to the inland during periods of heavy rains, staying in paperbark shelters (*gidun*). *Ngalandany* is the end of the Wet and literally means 'no fruit'. Temperatures and humidity are high, there is no wind, and during this 'rubbish time,' people move around as little as possible. *Iralbu* is the period of the king or big tides; the low tides are ideal for reefing. There is much fruit available such as the ngurngulu (*Avicennia marina*) fruit, which indicates that it is time to shift camp to beaches and high dunes to avoid mosquitos. *Bargana* is the 'cold' season when people start to light night fires. This is the hunting and fishing season through though tides.

The Wurdeja, Ji-malawa, and Yilan of central north Arnhem Land [1.1.5c] in Northern Australia Aboriginal communities of central north Arnhem Land, have developed a calendar with four seasons that are based in language and cultural activities, each season has its own patterns of winds and weather, plant growth and cycles of animal life and death. This knowledge assists these communities in knowing the appropriate time for hunting and gathering, burning and ceremonial life. For instance, 'when the leaves of the yam plant change colour, the communities become aware that it is time to clear the land for new growth through burning bushes. (Green *et al*., 2010).

Miriwoong people in the East Kimberley [1.1.5b] of Western Australia break the year into three distinctive seasons: Nyinggiyi-mageny (wet season), followed by Warnkamageny (cold season) and then Barndenyirriny (hot season). To predict seasonal and climatic changes, animals and plants behaviour are observed. In the Keep River, for instance, Miriwoong people observe that the flowering of the *Gali-Galing* (Fern-leaf grevillea) indicates the beginning of the cold season and a good time to undertake tradition burning practices to prevent late hot season fires that damage the landscape (Green *et al*., 2010).

The Aboriginal people of north-east Arnhem Land [1.1.5c] (Australia) also recognize six seasons, each of which is clearly identified by distinct changes in the flora, the fauna, and climatic conditions. Similar traditional knowledge entails the observation of the ocean colour, waves, and the wind is used to forecast extreme weather conditions in the Pacific Islands (Nakashima *et al*., 2012).

The cabbage tree/tï köuka is common throughout farmland, open places, wetlands and scrubland of the North and South Islands and it prefers full sunlight, Consequently, Aotearoa people in New Zealand [1.1.5d], observe flowering of this species. Early and profuse flowering of Tï köuka Cabbage tree is an indication that a hot summer should be expected.

In Vanua Levu [1.1.5f], Taveuni [1.1.5g], Kioa [1.1.5h], Qamea [1.1.5i], and Rabi Island [1.1.5j], Fiji to forecast heavy rainfall or strong winds, communities carefully observe clouds, waves, winds, sun, and the stars. For example, for clouds, changes in texture (thin or thick), color (white, dark, yellow or red), location (over mountains or the sea), and movement (to/from the coast), including speed (fast) and direction (vertical or horizontal) are observed (Janif *et al*., 2016). Animal, insects, and plant behaviour are also used to predict weather conditions. In Fiji extreme fruiting of breadfruit and mandarin (Citrus spp.) is an indication of the approaching extreme weather conditions (Janif *et al*., 2016). When hornets begin building their nests closer to the ground than usual, it is an indication that a tropical cyclone is approaching.

In Aceh [1.1.5e], Indonesia, a foul odour emanating from the sea signified the coming of a storm or typhoon.

In the East Kimberley [1.1.5b] of Western Australia, when (Fern-leaf grevillea) Grevillea pteridifolia bears its bright orange flowers Miriwoong people know the cold season has arrived (Green *et al*., 2010).

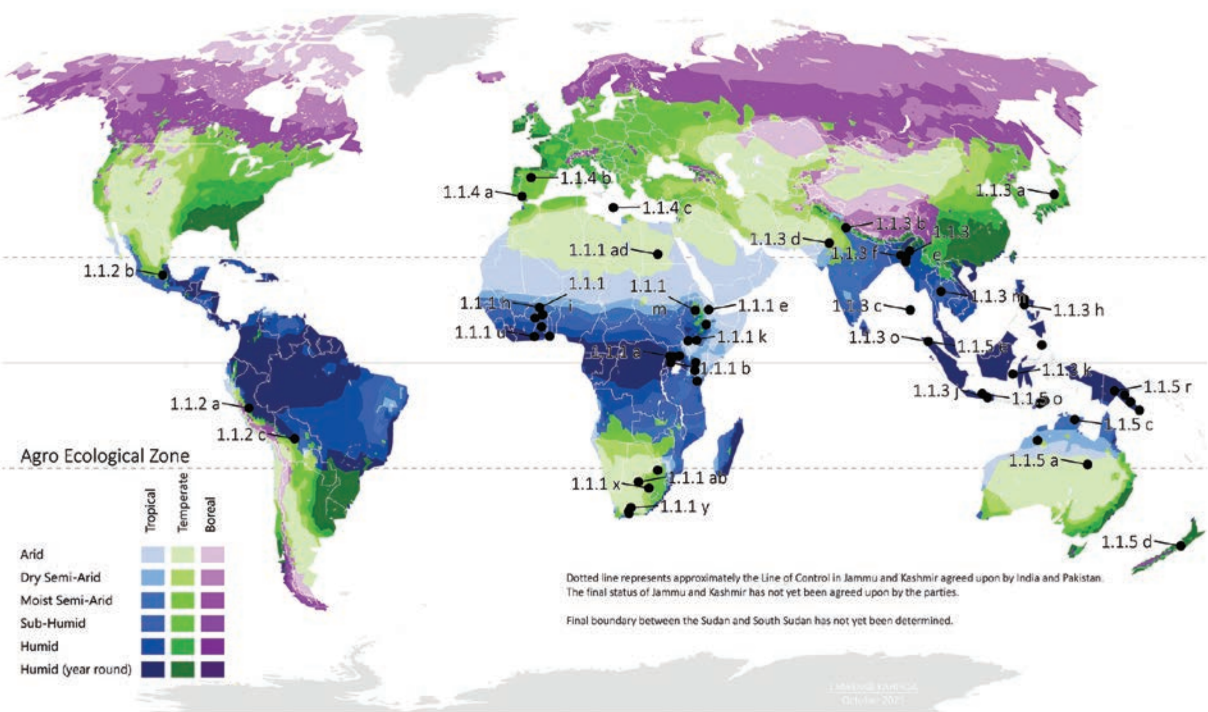
In Raimea [1.1.5k] and Lau-Hata [1.1.5l], Timor-Leste [1.1.5m], leaches and caterpillars are observed before storms.

The migration of birds are important signals of changing seasons and their prolongation, as well as heavy rains, storms, or droughts, in Raimea [1.1.5k] and Maluru-Beaço [1.1.5n], Timor-Leste [1.1.5m], and Sayung [1.1.5o] and Lipang [1.1.5p], Indonesia. In Vatulele Island [1.1.5q] when the central unfurled leaf (uvu-na) of the vudi plant bent down rather than pointing straight up is a signal of bad weather, possibly a tropical cyclone is approaching.

The coastal and small island communities have long histories of noticing changes in the environment and have a collective wealth of knowledge and practices connected to these changes, local knowledge has been utilized to design traditional seasonal calendars, these communities have also developed traditional mitigation and adaptation strategies for climate change (Hawasaki *et al*., 2014).

Indigenous communities in Papua New Guinean [1.1.5r] have experienced a range of disasters, these communities have employed a number of strategies to cope with the impact of climate change. Traditions and practices have affected the process of local communities forestall and adjust to extreme weather events (Sithole *et al*., 2015). For instance, the communities observe different environmental changes thus enable them to employ appropriate strategies. In Popondetta [1.1.5s], Papua New Guinean, cold breeze or thunder roars coming from the mountains are an indication for a cyclone or heavy flood approaching, while; in Bulolo [1.1.5t], cyclones are indicated by the emergence of a rainbow, while wave noises are associated with tsunamis (Sithole *et al*., 2015). In addition, in Bulolo [1.1.5t] and Labu [1.1.5u], Morobe, when the leaves of the Xuc tree start falling between November and December, signals Drought, while in Popondetta, Oro if florae blossom in a certain colour and flowers fall from trees thus signals dry spells.

Figure 2. Geographical locations of narrated weather forecasting and early warning systems case studies



Source: World Bank, 2021 & Plevin *et al.*, 2014, modified to comply with UN Geospatial. 2021. *Map of the World*. Washington, DC, UN.

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TOPIC 1.2. GRAZING AND LIVESTOCK MANAGEMENT

Across the world, pastoral communities are making use of their "in-depth knowledge" of indigenous rangeland assessments techniques, which inform their land use arrangements. Each day, herders monitor and observe the condition of rangelands and thereafter decide grazing for their "multi-livestock species" (Homewood and Rodgers, 1991; Cotton, 1996; Mills *et al*., 2002).

Grazing and livestock management in Africa

In northern Tanzania [1.2.1a], Maasai herders make use of "socio-cultural folk systems, soils, topography and vegetation, management knowledge and seasons of grazing" to identify seasonal grazing lands. The herders have developed a method that characterizes degradable land from non-degradable, in response to heavy grazing pressure (Oba and Kaitira, 2006). The method is used to help the herders regulate seasonal grazing for different landscapes. Significantly, the degradation now observed in the Selela landscapes (Tanzania) was a result of traditional grazing systems being changed by crop cultivation. Past observations have been used to establish a shift in plant species composition and the loss of "key forage species" and an increase in species less desired by livestock was used as signals of degradation (Oba and Kaitira, 2006). The landscape interpretation reflects strong cultural values and special experiences, while an emphasis on the ecological purpose of grazing. More so, the interpretations of landscape change have helped the Massai herders monitor environmental change.

In the Central Plateau of Burkina Faso [1.2.1b], Bonam village [1.2.1c] (Mossi tribe), certain trees are significant for predicting seasonal rainfall and guiding agricultural activities. When the sigba tree starts to bear fruits and the sabtuluga tree loses its leaves, farmers know, the time to plant has arrived (Roncoli *et al*., 2002). Moreover, the Kangana tree grows along a water table, near the soil surface which indicates where the herders should dig wells to provide water to their livestock and where they can plant water demanding plants such as cotton (Roncoli *et al*., 2002). The ability to observe trees allows farmers and communities to manage the impacts of a changing climate.

A traditional water conservation method of Central and North Darfur [1.2.1d] (Reij *et al*., 2013) that involves harvesting runoff water by constructing low earth bunds called *trus* (tera, singular). The technique probably has its origins in the home garden (*jubraka*) operated by women growing quick maturing crops

and some vegetables like okra, pumpkins, and cucumbers. When villages grew in size and more livestock were kept at home, women began to extend *jubraka* activity to areas away from home. This practice became important in recent years, as rainfed farming on sandy soils had become increasingly risky and unable to produce sufficient food for families (Osman *et al*., 2006).

The Tin Aicha and Ras El Ma Communities of northern Mali [1.2.1e] have also developed different practices for adapting to environmental changes and climate variability (Brockhaus *et al*., 2013). Adaptation strategies remain centred around livestock and agriculture activities. The most dominant strategy for adult men is the "transhumant livestock husbandry (cattle, sheep, and goats). They describe this as the "the soul and the proud of a Tamachek pastoralist" and a chance to be a part of a larger social network aimed at reducing climate variability because of "heterogeneity of rainfall and fodder" (*Ibid*).

In Niger [1.2.1f], the Tuareg nomads have safeguarded and revamped their pastureland through pasture-management associations; thereby reinforcing the resilience to both climatic and non-climatic pressures (New Agriculturist, 2009).

The Turkana pastoralists [1.2.1g] in northern Kenya, and Sukuma agro-pastoralists in Shinyanga [1.2.1h], Tanzania, have rehabilitated degraded woodlands through the improvement of local institutions for natural resource management (Barrow and Mlenge, 2003). The Turkana rehabilitated over 30 000 ha and the Sukuma 250 000 ha of woodland; which has resulted in a reduction of risks connected with droughts (Barrow and Mlenge, 2003).

In the Ethiopian Borana [1.2.1i] rangelands, pastoralists have maintained their nomadic methods but are replacing their cattle herds with camels, which feed on trees and grasses and can survive long periods without water. For other pastoralist groups, adjusting involves adjusting alternative livelihood options, although income-generating opportunities are often restricted in remote dryland areas. The scarcity of market access for adding value to livestock products is a general restriction (New Agriculturist, 2009). In the long-term, it is possible that pastoralists may even benefit from climate change. In West African Sahel [1.2.1j], changing from cattle to sheep and goat husbandry has demonstrated to increase the resilience of communities in regard to adverse climatic conditions during dry periods and droughts for pastoralists and agro-pastoralists.

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Nomadic mobility minimizes the pressure on low carrying capacity grazing areas through the circular movement from the dry northern areas to the wetter southern areas of the Sahel and continuously from South to North when conditions improve (Nyong *et al*., 2007).

In the Mossi region [1.2.1k]of Burkina Faso, most farmers during the dry periods fattens their animals' especially old oxen and bulls in other to ensure good market prices (Barbier *et al*., 2009).

In southern Ghana [1.2.1l], erosion is controlled by redirecting gullies from farms to avoid flooding (Yaro, 2010). Generally, small channels and gutters are made in most farms and also around the communities to ensure that the flood waters do not remain in the communities and farms for long periods (*ibid*). Planting cocoa seedlings closely with small intervals to ensure the survival of some when others are unable to survive is another method used in southern Ghana. This strategy helps early cocoa plants from the direct heat of the sun, farmers raise plant shading trees to cover these cocoa plants. Planting of minor crops such as cashew, tomato and tiger nut to reduce the level of risk rather than traditional crops such as cocoa and oil palm (Yaro, 2010). Diversification, adjusting planting dates, and changes in crop varieties planted are crucial adaptive strategies. Coping strategies buy time for people to successfully plan the future based on the past and imagined scenarios of what trends will occur (*ibid*).

As environmental change has already strained their livelihoods in the past, indigenous peoples have established specific coping strategies to intense imbalances of weather. Such as changes in food storage methods, drying or smoking foods according to climate variability and accessibility of food (Macchi, 2008), crop diversification in order to reduce the probability of harvest failure (diversity of crops with differing susceptibilities to droughts, floods, pest etc. are grown). Some of these varieties are adapted to different environment/field locations (near rivers, high on mountains, close to a primary forest etc.) (*ibid*).

In Tanzania [1.2.1a], sustainable grazing on slopes is a special practice of the Maasai pastoralists (Mapinduzi *et al*., 2003). The presence of more trees than grass is an indication that an area is not suitable for cattle grazing. Such an area is, however, suitable for small ruminants grazing.

Collective, sustainable management of rangelands is one of the strategies used by many rural communities of South Africa. In Bergville [1.2.1m], KwaZulu-Natal, the management of stock and land resources is governed by Traditional Authorities (Hart and Vorster, 2006). In the Karoo, Western Cape [1.2.1n], farmers create camps to conserve grazing lands, destock or migrate animals to better grazing lands (Ncube and Largedian, 2015). Stock reduction, shifting of stock to higher carrying capacity camps, and supplemental feeding and water provision is the key strategies employed by farmers in Southern Africa, for instance in KwaZulu-Natal during the summer months, farmers farm on the highveld, and move with their animals to the low veld and during the winter months when it becomes very cold in the highveld and only the unpalatable sour veld remains (Jordaan, 2011).

As in many other parts of eastern Africa, livestock is a significant component of the agricultural system in the Tigray [1.2.1o] highlands (North Ethiopia). In the crop-growing season, transhumance is practised on a wide scale in the open-field areas of Tigray [1.2.1o], as farmland and stubble are not accessible by livestock (Nyssen *et al*., 2009). Transhumance is a livestock production systems where the herd is moved between fixed points and following precise routes, to maximize the seasonal availability of grazing resources over a year.

Herds in the village of Adi Geza'eti (2 580 m) [1.2.1p] are brought each summer to the gorge of the River Tsaliet (1 930 m), where riparian vegetation exists. The young shepherds created enclosures and places to sleep, either in rock shelters or in the open air. The first to arrive choose the best places. The shepherds remain there until after the harvest, when the oxen are needed for threshing operations and when the herds are fed by stubble grazing. As this takes place during summer school holidays, young boys who are in school join with those who are not. This is the most frequent method of practising transhumance in the area.

In Kokolo village (2 060 m) [1.2.1q], the herds are taken to the Geba River valley (1 680 m). This case is very similar to the previous one, with the exception that one of the village families are chosen to reside in the valley and occupies the best rock shelters and transform them into permanent cattle sheds.

The villages around Mount Kemer (2 440 m) [1.2.1r] in the Gueralta plain experience different livestock migration patterns, depending on accessibility to the mountain, which is composed of a foot slope, a very high cliff, and an undulating top plateau. From Korkor [1.2.1s] and Da Tsimbia [1.2.1t] (2 000 m), the herds are led toward the upper slopes of Mount Kemer (2 200–2 300 m) [1.2.1r]. During the rainy season, there are many water holes and there is much lush vegetation. Whereas the herds from Da Tsimbia [1.2.1t] usually return to the homesteads for the night, those from Korkor [1.2.1s] are taken through a difficult mountain pass and hence are kept overnight on the grazing lands.

The flocks belonging to the slightly urbanized Megab (2 050 m) [1.2.1u] are only taken to the foot slopes of Mount Kemer [1.2.1r]. People from this area do not bring the livestock to the lowland areas more to the west, as they maintain that the land belongs to other villages.

The herds of Agewo (2 840 m) [1.2.1v] descend the western escarpment of the Rift Valley, which is a day's walk. This is a region with seasonal springs, and it is much less populated. It is a shared territory in which Afars [1.2.1w] and Tigrayans [1.2.1x] are involved in Intensive and extensive interaction. Livestock is kept there throughout the rainy season by adult men. Conflicts with the Afar are not frequent, but memories of past fighting and cattle raiding are still recalled.

Hidmo (1 450 m) [1.2.1y], a village in the lowlands with high temperatures and water shortages, is located some 9 km from Tekezze River, one of the major tributaries of the Nile. The river flows in a deep gorge, the slopes and shoulders of which are used as a Transhumance Destination Zones. Rangelands are much wider across the river on its west bank, and the inhabitants have developed a bimodular transhumance system. Throughout the dry season, livestock is herded across the river to Chow'eh, an area in the Amhara region [1.2.1z], a day's walk from the village. The flocks are herded by adult men on a rotational basis, but not by children, as Chow'eh [1.2.1z] is far from home and both the river crossing and the livestock watering are unsafe owing to the presence of crocodiles. In addition, many children have started to go to school in recent years and dry season transhumance here starts in the middle of the school year. The magnitude of transhumance in the dry season depends on the previous year's harvest: when there is little straw, most people will bring their livestock there. Otherwise, only half of the households participate in transhumance. Conflicts with the Amhara cultivators on the other side of the river are rare. In the summer rainy season, livestock is herded on the eastern, nearby banks of Tekezze River, which at that time is impractical to cross. The shepherds are young boys, and the practice is very similar to the one described for Kokolo [1.2.1q] and Adi Geza'eti [1.2.1p]. On the left bank of the Tekezze, the Amhara also bring their livestock down to the river. They never need to cross, as there is more grass on that side.

People from Antshel [1.2.1aa] have never practised transhumance. Until some 12 years ago, livestock was taken daily for grazing to Bereha Antshel [1.2.1aa] and brought home in the evening. In recent years, these slopes have become exclosures and the area has drastically changed. Vegetation has grown, infiltration is enhanced, and springs have developed. As every potential rangeland area has become an exclosure, livestock is kept in and near the homesteads; grass is cut from the closed areas and pure water is available in newly arisen rivulets.

In Gobo Dogu'at (2 690 m) [1.2.1ab] and Gabien [1.2.1ac], livestock is not subject to transhumance. The herds of Gabien village are kept in the village, feeding year-round on edaphic grasslands on the wetlands in the centre of the village. Gobo Dogu'at's [1.2.1ab] livestock are taken down daily to the valley in the lower part of the village near Gabien. Regardless of the fact that an ancient man-made foot tunnel provides access to bushy areas in the west, livestock is not taken there because it was announced that those areas belong to another village.

Farmers of Akeza [1.2.1ad] do not take their livestock down the Rift Valley [1.2.1ae] escarpment, as there are no areas with sufficient access to water. Previously, a few springs and some pond water in the rainy season allowed livestock to be kept in the village. Transhumance started only in recent years after the Hashenge earth dam and reservoir were built in 1997 within the plateau, some 5 km from the village. Presently, around half of the village stock is herded by children to the reservoir during the rainy season and remains there the whole season.

In the Guji zone [1.2.1af], south Ethiopia, farmers combine livestock and crop production to diversify

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household income and adapt to drought conditions. Traditional grazing land management practised include *kaloo jabi*, which is a form of enclosure used mostly for calves (Abate, 2016). Communal enclosures, controlled by *Abboti Dedha* (the elderly people), are accessible to all members of the community when feed resources are consumed in the communal grazing areas during the dry season. These communal enclosures, located around homesteads and farmlands, are predominantly used for feeding lactating cows, calves and weak or sick animals during the dry season. Communities from the Guji zone [1.2.1af] have two categories of grazing landscapes, the *Badaa* [1.2.1ag] and the *Gamoji* [1.2.1ah], which used a combination of climate (rainfall and temperature), soil, vegetation and topography (Abate, 2016). The *Badaa* landscape is characterized by prominent amounts of rainfall, cool temperatures, highlands, and dense vegetation cover. This landscape, dominant in the Wadera [1.2.1z] district, is used for dry season grazing. The *Gamoji* [1.2.1ah] landscape experiences low rainfall patterns, warm temperatures, lowlands, and scarce vegetation. This landscape, commonly found in the Wadera [1.2.1z] district is mostly used for wet season grazing.

One of the common practices used by the farmers is diversified herd composition and division of herds depending on animal species and class. Some farmers separate their herd into *warra* herds (village based) and fora herds (satellite herds) (Abate, 2016). The *warra* herds consist of calves and small ruminants which are kept around the homestead, as were animals under production (lactating cows), sick animals and calves during the dry season. Whereas the fora herds which comprize heifers, bulls, camels and dry cows, use pastures and water remote from the homestead during the wet season. During the dry season, animals are moved towards water points and use forage resources found at Meta Tika. Furthermore, farmers also practice seasonal herd mobility. The extent and direction of movements are determined by the availability of rainfall, water feed, and security. During the dry season livestock (bulls, heifers, cows, camels, sheep, and goats) are moved to remote sites where feed and water are abundant. Household heads and boys (15 years of age) are responsible for the migration of the animals.

Farmers from the Somali region [1.2.1ai] of eastern Ethiopia, use traditional grazing times for their animals (Kassahun *et al*., 2008). From 06:00 – 12:00 and 14:00 – 18:00, animals resting in the shade of trees grazed from 12:00 – 14:00. Each animal is randomly selected to graze for four weeks. Observations are recorded for four hours each day (two hours before noon and two hours after noon) per animal. This is done at a 5m distance from the animal using binoculars.

In the northern Kunene Region of Namibia [1.2.1aj], the Himba community herders jointly manage natural resources like rangeland and water. They apply seasonal-dependent rangeland use, and conservation of reserves for drought periods (Müller *et al*., 2007). In the rainy season, the livestock grazes on the grass around the households to allow communal rangeland to recover. Herdsmen also hold back some areas for drought in order to manage very low rainfall and fodder production. These reserve areas which are not easily accessible, are located far from water sources. Herdsmen can only access these pastures in cases of emergencies during drought periods. This traditional practice is increasingly disappearing. Because of the heavy impact of grazing throughout the year, rangelands were dominated by annual grasses and herbs and the dry season pastures were mostly covered by annual grasses (*Schimdtia kahahariensis*). In areas where grazing was not practised, perennial grasses, mainly *Stipagrosis uniplumis* dominated on both rainy and dry season pastures (Müller *et al*., 2007).

Many pastoralists worldwide use management strategies where pastures are rested during the rainy season for use in the dry season (e.g. Turkana [1.2.1g] of Kenya and Jie of Uganda [1.2.1ak]) (Müller *et al*., 2007). During the rainy season, productive areas with temporary water access are. Turkana pastoralists use some of the least productive rangelands in the rainy season and moderately move to areas of higher productivity as the dry season begins (Müller *et al*., 2007).

Herd splitting is a practice that involves the separation of livestock into distinct herds based on their sex, type, age, and productivity. Rendille pastoralists of Northern Kenya [1.2.1al], between the Marsabit hills [1.2.1am] and Lake Turkana [1.2.1an], regularly separate large ruminants from small ones, as it is done by the Tuareg of Niger [1.2.1f] (Niamir, 1991).

In the Fulani [1.2.1ao] of northeastern Senegal and Dinka [1.2.1ap] of Sudan, livestock is separated into a milking herd (mainly milking and pregnant animals and their young) and a main or dry herd (Niamir, 1991). Herd splitting increases niche specialisation and reduces competition between livestock for the same feed, and reduces grazing pressure as each livestock is placed in the pasture which best suits it. Therefore herd splitting and diversity are practices used to conserve long term productivity of pastures and improve degraded pastures.

Zaghawa herders of eastern Chad [1.2.1aq] use traditional range management practices such as moving their sheep and camels between the north and the south (Niamir, 1991), except, during drought periods.

Pokot herders of Kenya [1.2.1al] use areas with termite-resistant grass during the wet season in order to protect good fodder for the dry season. Home-based herds (goats, calves (*lukuyan*), lactating cows (*oboe*), and sick animals) are left at home during the dry season grazing movements. Dry season grazing areas consist of perennial grasses with permanent water sources, on the hills. Pastoralists move to these areas as soon as surface water sources in the lowlands dry up and forage has been exhausted; usually in June and January. The lowland areas provide wet season grazing for livestock and are dominated by annual grasses. Furthermore, the Pokot farmers use mixed species herds (goats and camels) as assurance against

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droughts (Nyariki *et al*., 2005), because they are more drought resistant than cattle.

Maasai herders [1.2.1ar] broaden their grazing radius and delay entering dry season areas by using donkeys to transport water into grazing areas.

The Wodaabe [1.2.1ao], also known as the Mbororo, are a small subgroup of the Fulani ethnic group use lunar cycles to schedule livestock movements to new pastures. This leads to moving grazing areas every two to three days (Niamir, 1991). Although the system is common to all the Fulani communities, it is particularly implemented by the Wodaabe herders. The Fulani of northern Nigeria [1.2.1as] moves grazing areas at least four times each season to prevent overuse of pasture.

Herders closely observe their livestock and environment for signs that indicate the need to move (Niamir, 1991). For example, the Wodaabe farmers [1.2.1ao] observe livestock faeces, milk yield, animal weight and the number of cows in the heat to assess the quantity of forage. Farmers in Fulani of Mauritania [1.2.1at] evaluate range quality by taking the livestock to the same pasture on an experimental basis for seven consecutive days. During this period soil types, presence or absence of key forage species, livestock behaviour (sleeping pattern, eating schedule, and hair and skin quality), as well as the presence or absence of wildlife are examined. The Samburu farmers [1.2.1au] observe grass and browse availability.

In some ecological zones, rotational grazing practices are used (Niamir, 1991). In Fulani of northern Sierra Leone [1.2.1av], farmers overgraze one area for 2-3 years then move to a different place and rest the first grazing area for 15-20 years. The Sukuma [1.2.1aw], south of Lake Victoria do the same but allow a rest period of 30-50 years. However, not all ecological zones are resilient to overgrazing, such as the Fulani of Nigeria [1.2.1as] where farmers send their excess livestock to neighbouring territories.

Orma herders [1.2.1ax], eastern Kenya, also apply the seasonal rotation grazing system between landscapes. They achieve it by managing grazing movements between the different *Mata dedha* associations (elder councils of grazing associations) during different seasons. The wet season grazing landscapes are utilized throughout the rainy season when the rain pools are full of water. Immediately after the pools are empty, the communities return to their traditional dry season grazing lands (the river floodplains of the Tana River and the delta). As soon as the rains resume, the livestock is returned to wet season grazing lands. The Orma's indigenous knowledge of range movement is determined by soil type and vegetation. Orma herders [1.2.1ax] use the white-grey soils landscapes (*oomaar*) for dry season grazing because livestock that grazes on it do not lose body mass, even during stressful periods (*Ibid*). Whereas the black soil (*kooticha*) is suited to wet season grazing. Range scouts (*abuuru*), young experienced herders are sent by the elders to assess rainfall and forage conditions (Oba, 2012). The Orma identified three types of pasture conditions based on different types of rainfall and livestock grazing. The *koono* rains that occur in the dry season stimulate the growth of browse vegetation, but is insufficient to maintain the growth of grass, and therefore livestock does not migrate to such areas. The second type of pasture is a result of heavy rainfall, which encourages high growth of pasture. This is also known as *ooba*, which describes high biomass. The last type is an overgrazed rangeland (*hinbarbadoofte*), avoided by the herders.

The Afar herders [1.2.1w] of Ethiopia move between grazing landscapes located in different topographies, the uplands (*ale*), the lowlands (*Bahari*), and between narrow (*duulul balaa*) and wide (*daaba*) valleys within the Afar rangelands. That rangeland extends between Ethiopia, Eritrea [1.2.1ay] and Djibouti [1.2.1az]. The floodplain of the Awash River serves as a dry season grazing reserve and the uplands are used for wet season grazing (Oba, 2012). The plains are used for grazing immediately after the rains (when grasses flowered and soils dried). During the wet season, neighbouring clans share water and grazing. The Afar clan leaders (*makabantu/makaban*) play an important role in decision making with regards to clan grazing lands. Clan leaders also set aside grazing lands to cope with drought periods. The conservation of grazing lands came about through agreements amongst the clan leaders.

The Matheniko pastoralists of Karamojong [1.2.1aaa] in Uganda use seasonal livestock grazing systems which depend on the assessments made by the traditional range scouts (*ngikereba*) (Oba, 2012). Farmers grazed livestock on black soil (*arro*) landscapes during the dry season and on sandy landscapes (eketela) during the wet season.

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Grazing and livestock management in America

Farmers and peasant communities in Brazil [1.2.2a] used improved pastures (*Brachiaria* grasses) and tree fodder species (*Leucaena Leucocephala*) which have the economic benefits of increasing animal productivity and diet (Vermeulen and Dinesh, 2016). *Brachiaria* is a plant in the grass family native to Southern America [1.2.2b] (Rao *et al*., 2014). Experiences in Brazil [1.2.2a] have proven that these pastures contribute significantly to farmers' income by extending animal productivity by five to ten times as compared to native savannah vegetation. Breeding practices of *Brachiaria* are being used, producing three commercial cultivars, Mulato, Mulato 2 and Cayman. *Brachiaria* bred cultivars aid in high productivity of livestock, nutritional quality and are tolerant to dry seasons. Deep-rooted *Brachiaria* grasses store large amounts of carbon in deeper soil layers (Thornton and Herrero, 2010).

In Jamaica [1.2.2c], bauxite soils are also known as "red earth" or "Terra Rossa" (Snaith, 1973) are shallow, prone to erosion, droughty and relatively infertile. These soils have been traditionally used for growing pasture species to assist ruminant livestock production (Williams *et al*., 2007). Their production practices incorporate the use of goat manure compost which is applied to crops to provide nutrients and enhance soil health and fertility. Crop by-products serve as a source of food for livestock and mulch to reduce soil and water losses. Furthermore, farmers also incorporate biochar, 2 000-year-old practice charcoal used as a soil amendment, to increase soil fertility and reduce pollution while providing carbon sequestration (Woolf *et al*., 2010).

In the Caribbean Islands [1.2.2d], farmers use well-adapted livestock breeds raised rustically, using natural and local feeds, traditional housing and breeding resources and methods (González-García *et al*., 2012). These breeds include Creole cattle or Creole pigs from the French Antilles and Spanish-speaking islands (Cuba [1.2.2e], Dominican Republic [1.2.2f], and Puerto Rico [1.2.2g]) and the Creole goat. Using well-adapted livestock increases their resilience.

Farmers from the Caribbean islands practice traditional mixed farming system strategies (González-García *et al*., 2012). In sugarcane producing countries (Cuba [1.2.2e], Dominican Republic [1.2.2f] and Haiti [1.2.2h]), draught animal power (pairs of adult bovines) is used to prepare the land and transport. They also intercrop cassava or maize and beans. Grains and cassava (root) are used for domestic consumption; while crop residues (straws and stems) are used for animal feeding.

Grazing and livestock management in Asia

In Nepal [1.2.3a], transhumance pastoralists have developed and used unique institutional practices of using and managing High Altitudes rangeland resources that better suit their context (Aryal *et al*., 2014).

Transhumance grazing systems – Kalinchowk [1.2.3b] and Bhairabkunda [1.2.3c] area, a village council comprising 9-15 members is formed democratically by the local community. Transhumance herders are assigned based on the quality of the pasture, and size of herds. Grazing schedules to move (upwards and downwards or during summer/winter) are pre-set; Rules for wood and non-timber forest products harvesting is made; Livestock taxes are defined. The Chief of the councils or a person or group of households are elected by the council for a specified period (usually one year) to act as the "Enforcer"; while the other members of the councils are responsible for supervision, monitoring, and reporting.

Shingi Nawa system of forest and pasture management - In the Khumbu region [1.2.3d], *Nawas* are elected democratically by the community on a rotational basis. Norms or rules on timings, areas of pastures, size of herds and sequence of rangeland for grazing and forest use (quantity by types and uses) and other accessory norms/rules required for sustainably managing natural resources are made. Two types *Nawa* exists; *Osho Nawa* and *Shingi Nawa* (*Shingi* stands for timber or wood and *Nawa* stands for people who look after forest). *Osho Nawa's* responsibility is to coordinate the villagers' agricultural activities and to prevent damage to crops. *Shingi Nawas* are responsible for natural resources management but also look after agriculture and livestock management. The head of local institution – the *Shingi Nawa* – enforces the rules and regulation and 3-4 men are specially appointed to monitor rules and regulation and also the assist the chief *Nawa*.

Gumba system of forest and pasture management - In Pungmo and Gumba Area of Dolpo [1.2.3e], *Chhabu* Lama – the chief Lama of Gumba danda monastery manages the system. Rules are related to banning on hunting and killing of wildlife including birds. Forest management/conservation and harvesting including non-timber forest products, managing and regulating grazing of pasture lands. Local norms related to agriculture system or crop management and laws related to offences and punishment upon breaches of the customary law. The *Chhabu* Lama is responsible for the enforcement of laws while his assistant Lamas are responsible for the overall implementation, monitoring and reporting of the local rules and regulations. The decision making process is democratic and bottom-up and often held at community and household level depending on the types and sensitivity of the cases related to the breaching of customary laws.

Transhumance grazing system - In Humla [1.2.3f], Jumla [1.2.3g] and Mugu [1.2.3h], rules and decision making are democratic, transparent and bottom-up and are carried out at the time of village councils before moving to summer pasture. Rules are made related to grazing cycles, harvesting of forests products and merging of animals and forming herd size, and fixing annual wages to Noras. The *Rokya* or *Mukhiya* are the main enforcers and Nora are responsible for implementing, monitoring and reporting. Rules and norms are revised at the time of village council while decisions against pasture/pasture offence or conflict between villagers are settled either at the community level or at an individual household level.

Transhumance Pasture Management – In the Nar and the Phu Valley [1.2.3i] of Manang, *Ghampa-Ngerpa*, and *Gamba-Lhenjing* (local village councils) make the rules. This institution is made up of two types of members, decision makers called *"Ghamba"* and decision implementers known as *"Chow"* in Nar Phu and *"Lenjing"* in Phu. These are clan-based institutions and rotational in membership. Each household heads (men only) hold both types of posts at least once in their lifetime. Rules are mainly related to regulation of forest harvesting, grazing, and protection of forest and cultural and religious sites. Grazing taxes are mainly revised on the basis of herd size and their age.

Sat Thari *Mukhiya* System of Forests and Pasture Management - In Baglung [1.2.3j], the chief of the Village Council is the *Mukhiya*. Rules are mainly related to the regulation of forest harvesting, grazing and protection of forest from encroachment and fire. Membership eligibility is based on residence (villagers only), age (15-60 years), and open to married men only. The overall responsibility of enforcing the laws lies on the *Mukhiyas*. However, each other members are also equally responsible for the implementation, supervision, and monitoring of activities. Decisions are democratic in nature and are made at the time of the annual village council's meeting.

The *Kipat* or *Subba* system of forest and pasture management system is employed in the Far Eastern region of Nepal (Aryal *et al*., 2014). Under this system, *Amali Subba* or *Pagari Subba* (the head of Amal), manage set rules for the management of land (agriculture), forests, pasture, and biodiversity, as well as rules for wildlife poaching and hunting; forest harvesting. They also set fees for use of forests/pasture and forest products for non-kipatiyas. The decision making process is democratic and bottom up. Issues are presented orally before community members and witnesses. Experienced and elderly persons from the communities are invited as a symbol of fairness and justice. The *'Amal'* (local court) is an institution that provides support and implements traditional practices and customary laws (Khatri, 2008).

The Bhotiyas pastoralists of the Kumaon Himalaya [1.2.3k] (central India), have for centuries used a farming and livestock management system different and unique from the rest of the Kumaon region [1.2.3k]. For centuries, Bhotiya has practised migration and vertical transhumance for grazing their livestock (Farooquee and Rao, 2000). Vertical transhumance is an important animal husbandry practice used by pastoralists living near mountainous terrains, assisting in the supply of a continuous source of quality graze throughout the year to livestock (Makarewicz *et al*., 2017). Professional shepherds take sheep and goats of the Bhotiyas down to the lowlands and foothills during the cold period, between May and September. Due to legal regulations, the shepherds are allowed to use one pasture for 10-15 days only (Nüsser and Gerwin, 2008). Nowadays, cattle are the preferred species for agriculture in the middle sections of the High Himalayan valleys within the vicinity of the former trade depots.

Bhotiyas pastoralists also allow their livestock to graze openly in the nearby forest and in the alpine meadows during the summer season. The alpine meadows of the western Himalaya [1.2.3k] are known for their high floral diversity (Farooquee and Rao, 2000). Access to grazing resources is uniform to all, and there are no specific tracts of land for any family. Due to the declining grazing resources in the Himalayan region [1.2.3k], customary institutions have provided the framework for sustainable use of rangeland resources by pastoralist communities (Miller, 1998; Banjade and Paudel, 2008; Pandey *et al*., 2017). Institutions are one of the crucial keys to sound natural resource management (Dong *et al*., 2009).

Similarly, transhumance sheep farming is practised in the Northern high altitudinal regions of Nepal [1.2.3a]. The chief herders move their herd upward in the early summers for utilizing the alpine pastures and downward in late autumn or in early winter to protect their herds from cold winter weather of the high altitude (Barsila *et al*., 2014). Additionally, cross-breeding of Yak (indigenous breed) is avoided, thus help support a higher performance of hybrid vigour and improved adaptation.

In China [1.2.3l], the grasslands are mainly distributed in the Inner Mongolia Plateau [1.2.3m], the Loess Plateau [1.2.3n] and the Qinghai-Tibetan Plateau [1.2.3o] (Liu, 2017). The Inner Mongolian Plateau grasslands are the most commonly used for grazing. Before, privatization of grasslands and the decentralization of herders, Inner Mongolian pastoralists practised a nomadic strategy, concentrated on seasonal migrations that allowed grasslands recovery after use (Conte, 2015). The traditional ecological knowledge of Mongolian folks is the basis for deciding, when and where to move the herd based on the preferred livestock plant species and seasonal dietary as well as water needs. This nomadic livestock management system significantly contributes to the sustainable management of the Inner Mongolian grazing land. It promotes the efficient utilization of grassland resources and the distribution of herds to available pastures (Conte, 2015).

The Tibetan steppe of Asia [1.2.3o], experienced substantial livestock losses. This has persuaded the authorities to restructure the transhumant pastoralism (Sheehy *et al*., 2006). However, currently, summer grazing lands are being privatized and fenced, except in the Tibetan Autonomous Region [1.2.3p] where rangelands are allocated to groups of herders rather than to households.

In the Dindori [1.2.3q] and Chhindwara [1.2.3r] districts, Madhya Pradesh of India [1.2.3s], two types of grazing systems are used, private and common grazing land. In common grazing land, animals are directed by rules and regulations for access to the variety of pasture categories. These grazing areas are logistically separated and are far away from intensive agricultural fields to refrain any conflict arising from undesirable trespassing and grazing of crops. Entrance to the different pasture and rangeland categories are controlled by the restricted accessibility of water at the peak of the dry season. Forage-banks in private

grazing lands and village forest are secured for weak and sick animals during periods of forage shortage (Singh and Sureja, 2007). Moreover, for the sustainable use of natural resources, they stratify their livestock and assign grazing land accordingly. For instance, calves (Bachhada) of both sexes (cow) younger than 6 months are kept in normal cattle shed with protected rearing and are frequently supplemented with forage, in addition, dry cows (Bishuki Gai) and adult males (Bail and Bachhada) move to more further pastures and cover a wide range of grazing. Livestock owners have secured lands, particularly for regenerating the vegetation and used as pasture land, while the common pasture land is governed and managed by the villages and availability for the outside boundary of the villages is restricted.

Pastoralists of the Nariyan village [1.2.3t], Iran, control their flocks by seasonally uniting them to the larger herd for increased yield in dairy production. Pastoralists use diverse methods to hold their herds together. The animals are trained to listen and react to specific words and sounds. These sound guide and direct them to the water or grazing ground, or they may prohibit movements. A bell is usually tied to a buck (*Kal*), because the pastoralists believe that the *Kal* is intelligent and responds very quickly in case of danger, warning the shepherd's dog to combat the danger. The sound of the *Kal's* bell indicates the speed of the herd's movement to all of the animals and prohibits the shepherd from falling asleep (Ghorbani *et al*., 2013). In terms of grazing land management, the pastoralists divide the rangelands based on their readiness of rangeland fodder plants and topographic conditions. The rangelands are separated into *Nesar* (behind the sun) and *Baraftab* (in front of the sun). Pastoralists closely observe the stages of plant growth, to avoid releasing flocks too early which will degrade the vegetation cover (Ghorbani *et al*., 2013). In addition, specific rangelands close to the village, known as the *Harim* or *Alaf Chin* (forage and cutting), are chosen by the Islamic Village Council for grazing a restricted number of larger animals (cows), and for cutting grass to be stored for winter feed. In the high and middle rangelands, an annual rotation system takes place to ensure equal access to grazing lands (*Ibid*).

Grazing and livestock management in Europe

Pastoralism in Europe [1.2.4a] has a tradition which dates back more than 10 000 years ago. Since the ancient time pastoralism has played a key role in the origin and maintenance of cultural landscape. There are two forms of mobile pastoralism, nomadic and transhumant. Transhumant is widespread across Europe and remains very important from both socio-economic and ecological perspectives. Transhumant pastoral systems can be found all over Europe [1.2.4a], from the Northern Arctic climates to the Mediterranean South [1.2.4b] and are characteristically found in mountainous ecosystems. In these highland–lowland systems, herds are moved according to seasonal cycles between fixed points at different altitudes, making use of grazing areas available at different times of the year. Herds are normally taken out for long periods and over great distances. Hence, herders either live near their herd in a hut or a secondary farm, or frequently travel between their distant farm and these pasturelands to watch over their animals (Gómez Sal, 2000; Herzog *et al*., 2005; Fernández-Giménez and Estaque, 2012; Oteros-Rozas *et al*., 2012; Mack *et al*., 2013 and Liechti & Bibe, 2016). This system assisted Mediterranean societies to cope with the unpredictable and highly fluctuating climate. Transhumance allows herders to make use of a wide range of different vegetation and terrain types available at different times of the year in different locations. However, many producers discarded transhumance in the 1970s and 1980s for various social and economic reasons. The main cause of the disappearance of transhumance is the increasing shortage and cost of renting pastures and stubble fields for winter grazing in the Ebro Plains (Fernández-Giménez and Estaque, 2012).

In the Austrian Alps [1.2.4c] transhumance systems, the animals were driven to the summer pastures in the Alps. During the winter times, the herd was kept in or near to the permanent settlements which were situated in the lowlands mostly outside of the Alps or near to the alpine fringe. On the other hand subsistence farming (*'Subsistenzwirtschaft'*) was also practised by the community (Bunce *et al*., 2004). A combination of lowland agriculture in the inner alpine valleys and basins, and the summer pastures in the sub-alpine and alpine altitudinal range.

In the Northern alpine fringe and Bregenzer Wald, cattle from Germany [1.2.4d] and Switzerland [1.2.4e] are brought to mountain pastures in Austria (*'Aufnehmvieh'*) and stay there during the summer (Bunce *et al*., 2004). This is specifically done in Vorarlberg as well as along the northern alpine fringe in Northern Tyrol.

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In south-eastern France (the Alps [1.2.4f], the Pyrenees [1.2.4g] and the Central Range [1.2.4h]), transhumant sheep systems (Crau's system) are dominant in the southern half of the country (the Alps, the Pyrenees, and the Central Range) (Bunce *et al*., 2004). The Crau's transhumant sheep system is characterized by animals spending their summer on alpine grasslands, autumn lambing, winter on the hay meadows, and spring (reproduction) is mainly spent on dry pastures (*coussoul* and fallow in the Crau and scrub in the hills).

In Spain [1.2.4i] different summer farming systems are practised.

In Asturias [1.2.4j] and Forollhogna, Spain, they use the *brañeo* system in which; different altitudes are used at different times of the year (Daugstad, *et al*., 2014). From October-November to March-April, animals are kept at the farm at village level indoors at night, and outdoors during the day depending upon the weather (*Ibid*).

South-west of Germany, in the federal states of Baden-Württemberg [1.2.4k] and Bavaria [1.2.4l] the Swabian-Franconian transhumance system is practised (Bunce *et al*., 2004 and Luick, 2004). Sheeps grazed in the upland areas of the Jura Mountains from late spring until late summer. Weather and growth conditions of the vegetation determined the journey to lowland wintering. On the 23rd of April (St. George's Day) shepherds arrived in their summer grazing areas and left on the 24th of August (The Feast of St. Bartholemew). The autumn grazing period lasted until the 6th of December (The Feast of St. Nicholas) (Bunce *et al*., 2004).

In Greece [1.2.4m], transhumance is a traditional pastoral activity linked with certain ethnic groups. Animals are kept on the lowlands to graze on common land or on fallow cropland during the winter period. During the summer period (four to six months) animals are moved to the uplands together with families to graze on forage and return back to the winter pastures during the early autumn months.

In the Western part of Lesbos Island [1.2.4n], Greece, rotational grazing was practised, together with small-scale transhumance between the western and the eastern parts of the island (Kizos *et al*., 2013). Farmers burnt the grazing lands in the western part of the island to 'clean' the field from *astivi* (*Sarcopoterium spinosum*) that is not palatable for livestock. The frequency of these burnings could not be provided as it is dependent on the particular field, the degree of astivi domination, and the weather.

In southern Norway [1.2.4o], pastures were used at different altitudes when they turned green in the spring and early summer as a result of the transhumance systems. Animals stayed at the spring and autumn farms for a couple of weeks. The stay at the summer farms usually lasted for a couple of months (from the beginning of July to the beginning of September). Customs determined dates for moving the animals.

In the mountain summer farm landscape of Innfjorden [1.2.4p], Western Norway, during the period of traditional farming, sheep were released from barns after lambing at the end of April or beginning of May (Bunce *et al*., 2004). The first grazing period occurred in the slopes close to the farms. At the end of May, sheep were moved to the mountains to graze the mountain outlands until the middle of September. Farmers from the main farms in Berild allowed milk cows to graze in the slopes close to the farms in May until the 20th of July. By that time, cows were moved up to summer farms for grazing the mountain grasslands until the end of August or the beginning of September.

Farmers from other parts in the village of Innfjorden [1.2.4p] also released milk cows from the barns in May, with the first grazing taking place in the slopes closed to the farms. The cattle were moved to spring farms throughout the last week of May or first week of June from the main farms for grazing (Bunce *et al*., 2004). On the main farms, milk cows were moved back for two weeks at the end of June or beginning of July for grazing the slope, throughout the hay harvesting period. Milk cows graze in the mountain summer farm region at Bøstølen [1.2.4p] and Svartrøsta [1.2.4p] from mid-July for approximately eight weeks. In the middle of September, milk cows were moved back to the main farms for grazing slopes close by. Hay meadows at spring/autumn farms were grazed by milk cows for two to three weeks. By the end of September, milk cows were moved back home for grazing on cultivated land of the main farms before being taken back into the barns in October/November.

Currently in Innfjorden [1.2.4r], Western Norway, sheep are grazing two to three weeks in May on cultivated land before being moved to the mountains

during summer. The final grazing period from mid-September is on cultivated land beside the main farms.

In the Jotunheimen [1.2.4q] mountains, Central-Norway, a special form of summer farming called "Mountain Winter Farming" was practised (Bunce *et al*., 2004). The livestock was taken to the mountains in autumn and kept in the stables of the summer farms to graze on the collected fodder and lichen, then transferred back to the permanent farms in the valley in late winter.

The slopes of the mountain-valleys in southern Norway [1.2.4o], have been of great importance for pasturing and hunting during the summer-autumn season (Bunce *et al*., 2004). The same area was used for a large number of tracks, such as transporting domestic animals from lowland to higher altitudes during the summer season. This kind of transport is further used for the movement of animals from lowland and alpine zones into the manmade pastures in the mountain valleys.

In Kalvøya [1.2.4r], Central Norway, summer farming is practised by the Borgan community (Bunce *et al*., 2004). Heathland is burnt, to increase the amount of grass and herbs for the summer pasture.

In the Stølsheimen [1.2.4o] mountain area, western Norway, mountain summer farming is comprized of pasture and dairy production (Bunce *et al*., 2004). Cows and goats were kept on some of the mountain summer farms. This area has occasionally been used for sheep and pigs grazing.

In Norway [1.2.4o], Vangroftdalen is one of the two major summer farming valleys of the Os community (Bunce *et al*., 2004). These areas were managed under a rotational system; each farmer owned two summer farms, one in each of the valleys. Traditionally the animals were walked up to the summer farms in early June and stayed there until early September.

In Røldal [1.2.4s], Western Norway, summer farming is dominant amongst the community (Bunce *et al*., 2004). In summer livestock (sheep, cattle, goats) from farms in distant parts of Ryfylke (e.g. Suldal, Kvinherad, and Etne) were transported to Roldal.

In Forollhogna [1.2.4o], Norway, farmers use one summer farm location for animal movement. In the past, farmers first moved animals to a summer farm in early June, where the pastures were ready for grazing. This first location was called the spring farm (*vårseter*) (Daugstad, *et al*., 2014). When multiple summer farm systems were practised, animals were moved at the end of June or early to mid-July (depending on ecological constraints) to the mountain summer farm (*fjellseter*) or the 'long' summer farm (*langseter*) (*Ibid*). Autumn farm (*høstseter*) animal movement has been practised in some parts of Norway. This comprized of movement in September back to the lower altitudes.

In the northern part of the Carpathian ridge of Poland [1.2.4t] and Ukraine [1.2.4u], the mountainous summer pastures are used by the shepherds and flock owners, to avoid grazing in more productive "lowland" areas (Bunce *et al*., 2004). During winter, sheep are kept in closed sheds and sometimes grazed in forest openings or inside forests. During extreme winters, animals are fed with spruce branches and needles. After the winter period, sheep are first moved to temporary pastures, and after a week moved to high summer pastures.

In some villages of Transylvania [1.2.4v], Romania, sheep are taken 2-300 km on foot from mountain villages in the southern Transylvania (the counties of Sibiu [1.2.4w], Braşov [1.2.4x] and Covasna [1.2.4y]) to "Ţara Românească" [1.2.4z] (south of the southern Carpathians until the Danube, also called Wallachia) and Moldavia [1.2.4aa] (east of the eastern Carpathians until the Ukraine) and sometimes to winter pastures in northern Transylvania. The need to find winter forage for the flocks has resulted in the practice of transhumance in Romania [1.2.4ab] (Bunce *et al*., 2004). Short-distance transhumant movements or "pendulation", which consist of peasant production of both cattle and sheep, is also practised in Romania [1.2.4ab] (Huband *et al*., 2010). Livestock in pendulation systems graze pastures in the summer months and kept in their home village in the winter months to feed on hay.

In Romania [1.2.4ab], herders also practice "transterminance", the seasonal movement of flocks within the same geographical region (Bunce *et al*., 2004). In summer, flocks are moved to high mountain pastures, from their village. This practice is driven by the need to produce winter fodder or hay. In the early summer livestock from the village, households are moved from their hay meadows and gathered into communal flocks during the summer. The livestock is

returned to the householders in the autumn to graze the cut hay meadows and is then kept in small barns during the winter and fed hay.

The current state of transhumance in Romania [1.2.4ab] is restricted. The main *transhumant* centres are in the area of Sibiu [1.2.4v]. Transhumance as it is practised today, one person (the shepherd camp owner) owns all, or the majority, of the sheep and takes full responsibility for their management and employment of shepherds to look after them. Approximately four to six shepherds are employed for the journey, whereby two are responsible for managing the flock and the others assist them. Between the beginning and the end of October, the flocks leave for the winter pasture. On the journey to the winter pastures, the shepherds find a place along the route to stop with their flocks for approximately one or two weeks. By doing this, they save money by renting the winter pastures. Nowadays, sheep are the only livestock that is *transhumed* in Romania [1.2.4ab]. The main breeds are (1) *Tigaie*, which is a *merino* breed, mainly a milk sheep breed. It is adapted to milder lowland conditions but is also kept in mountain areas, and the common breed in Brașov [1.2.4x] and Covasna [1.2.4y]; and (2) *Turcana*, which was raised by sheep producers in Sibiu [1.2.4w] (Bunce *et al*., 2004).

In the Alpine summer farms of Switzerland [1.2.4e], herders keep their domestic livestock inside for six to seven winter months, feeding them with hay and silage produced and harvested during summertime. However, fodder produced in the narrow mountain valleys was often not sufficient, resulting in a system of animal husbandry called *"Alpwirtschaft"* (*Ibid*). It consists of seasonal vertical migration of livestock (mainly cattle) over short distances.

In Hungary [1.2.4ac] forest belts, windbreaks and shelterbelts are used to protect crops and livestock from unfavourable factors such as strong winds (Mosquera-Losada *et al*., 2012).

In Spain [1.2.4i], the Conquense Drove Road includes the large ecosystems interconnected by a network of drove roads that start at the top of the Serranía de Cuenca mountain range in Teruel Province [1.2.4ad], cross Cuenca [1.2.4ae] and Ciudad Real Provinces [1.2.4af], and end up on the southern slopes of Sierra Morena (Jaén Province). This Royal Drove Road is Spain's last transhumance system still travelled by herds of merino sheep used for meat production and cattle (Oteros-Rozas *et al*., 2013). This system competes with stabled and intensive livestock farming methods and other land uses (particularly hunting and agriculture). Sheep flocks and cattle herds avoid the hot and dry Mediterranean summer by staying in the high mountainous areas, where they find food and water, from July to November. When snow begins to cover the mountain pasturelands (early November), most herds start a 25 to 30-day journey, crossing the central plateau on foot, heading towards the warmer pasturelands of the wintering areas located at southern latitudes and lower altitudes. Livestock remains for about six months before returning to the north in early June (*Ibid*). Other livestock species and breeds also involved in transhumance include *Lacha* sheep; *Tudanca, Asturiana, Morena; Avileña* cattle; and *Verata* and *Serrana goat* which are milk producers (Bunce *et al*., 2004).

In Doñana [1.2.4ag], southwestern Spain cattle breeding of *vaca mostrenca* was practised for its potential to move and survive in the marshland when flooded (Gómez-Baggethun *et al*., 2012). Livestock was moved to the higher parts of the marshland or to the sandy aeolian sheets during heavy rainfall. For example, to reduce vulnerability to floods during heavy rainfall, stockbreeders moved cows either to higher parts of the marsh (locally known as *vetas* or *paciles*) or out of the marsh. The scarcity of fences and communal use of pastures enabled seasonal movements of cows, sheep, and horses following the abundance of pasture or risk of flooding.

In southwestern Spain [1.2.4i] the sheep livestock system is characterized by one lambing every year in autumn. In the early summer lambs marketing and old ewes are eliminated from the flock, just before any shortage of natural grazing resources, or before conducting the sheep to the stubble area of the lower plains. Grazing lands are managed by destocking the pasturelands, resulting in longer rest periods (Joffre *et al*., 1988).

Traditionally the *Saami* migrated with the reindeer between the summer grazing lands in the mountains, feeding on grass, leaves, herbs, and fungi and in winter they move to forested land, where they feed on ground lichens. (Jeanrenaud, 2001). Reindeer herders from the mountain Sámi communities (*Gabna, Laevas* and *Girjas*), and the forest Sámi community (*Udtja*) in northern Sweden [1.2.4ah] had very good knowledge of which plants reindeers graze on, especially during

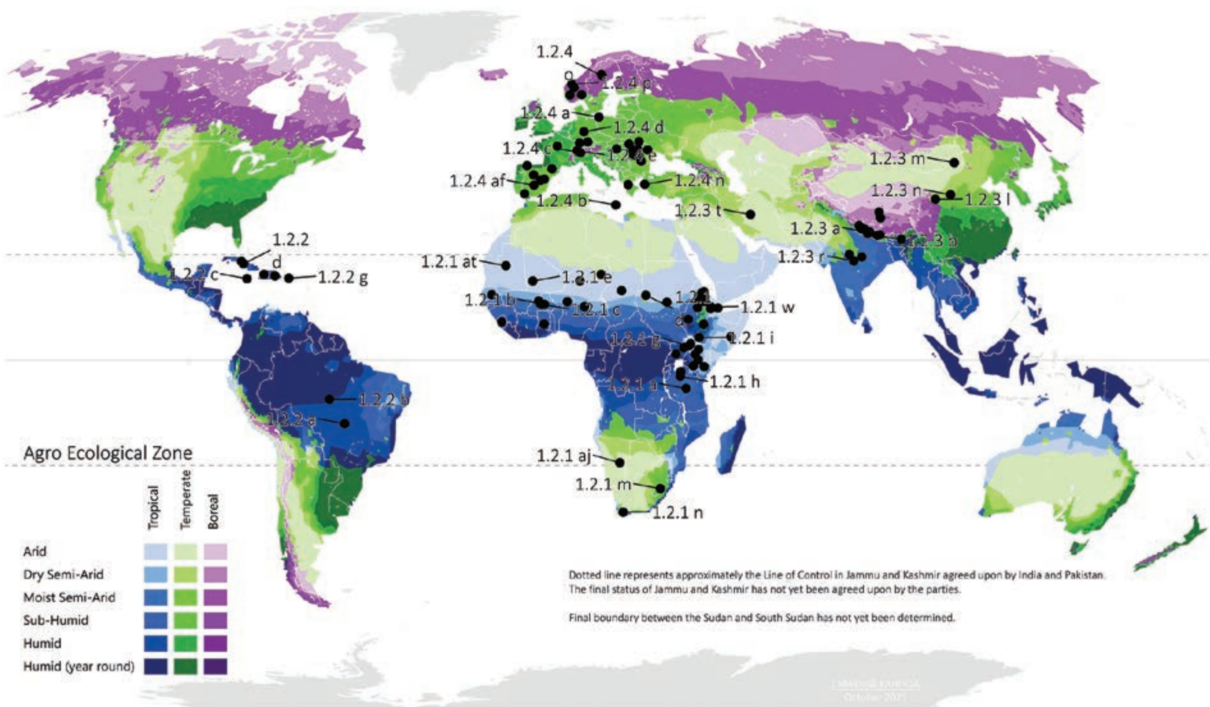
the autumn, winter, and spring-time, with a shortage of available forage (Inga, 2008). *Equisetum fluviatile* can be grazed when the snow covers the ground, as well as *Eriophorum vaginatum* during spring on the wetland. Furthermore, moist areas are utilized by the herders in early winter (Oct – Jan) and the drier areas during late winter (Jan – Mar) (Inga, 2008).

Traditional management practices were used by rural communities in Western Europe, for example in Sweden [1.2.4ah] (Ivașcu and Rakosy, 2017). The hay meadows are grazed after the cutting of hay. Sheep, cows, and horses usually graze all the areas where the crops have been harvested. This practice improves the quality of grass because the animals also manure the fields while grazing them. This type of grazing is done in two phases, in late winter/early spring time when the young grass springs up, and in autumn after the crops have been harvested (*Ibid*).

Grazing and livestock management in Oceania

No case studies of grazing and livestock management were found in the literature.

Figure 3. Geographical locations of narrated grazing and livestock management case studies



Source: World Bank, 2021 & Plevin *et al.*, 2014, modified to comply with UN Geospatial. 2021. *Map of the World*. Washington, DC, UN.

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TOPIC 1.3. SOIL AND WATER MANAGEMENT (INCLUDING CROSS SLOPE BARRIERS)

Soil and water management in Africa

Soil conservation practices have been widely adopted in Tougou [1.3.1a], northern Burkina Faso in the past few decades (Barbier *et al*., 2009). Adopted soil conservation methods include a process of corralling, where farmers enclose their animals on their fields during the dry season in other to ensure manure availability for soil fertility.

Furthermore, local farmers in the Sahel [1.3.1b] protect carbon in soils through the use of zero tilling practices in cultivation, mulching, and other soil management techniques (Schafer *et al*., 1989; Osunade, 1994). Natural mulches control soil temperatures and extremes, preventing diseases and harmful pests, and protect soil moisture. Before the development of chemical fertilizers, local farmers largely depended on organic farming, which also is capable of reducing GHG emissions (Nyong *et al*., 2007). Local populations across Africa, through their indigenous knowledge systems, have established and implemented extensive mitigation and adaptation strategies that have equipped them to reduce their vulnerability to climate variability and change.

In the Atakora [1.3.1c] and save zones [1.3.1d] of Benin, farmers believe that increased climatic variability (less and more irregular rainfall), runoff, erosion, and overexploitation of farmlands have caused land degradation. Soil fertility status is evaluated using dicotyledonous weeds, soil texture and colour, and soil fauna (earthworms casting activity) (Saïdou, 2006). Farmers have adjusted their cropping systems to the local environment by establishing traditional and new strategies and activities that could contribute to conserve or improve crop productivity. These strategies include animal manure, inorganic fertilizer, crop rotation, and a five-year fallow, extensive cropping systems with cassava or egusi melon, and migration. Significantly, in the North-Western part of Benin, the appearance of certain weeds on the land indicates to farmers whether the soil is fertile or infertile (Saïdou, 2006). Women on their individual or collective farms in the Atakora region [1.3.1c] of Benin often grow grain legumes, except groundnut in other to ensure soil fertility. Usually, other crops are grown after the legumes have been harvested (*ibid*).

Strategies to preserve soil fertility may not only include biophysical interventions. If the productivity

of the land cannot be adequately increased, pressure can be put off the land by migration. Migration is a strategy used by the younger generation. The older generation generally decides to stay and applies household waste, animal manure, or a combination of inorganic fertilizer and animal manure or household waste a way of enhancing soil productivity (Saïdou, 2006).

In the Ouémé Valley [1.3.1e] of Benin, the finger ponds previously dug in flood-plains to trap migrating fish during the flooding, have become preferred areas for agriculture. From simple holes, the finger ponds became agro-fishing techniques whose pits maintained their traditional use of fish ponds, but the dykes broader and forming high strip lands are used for dry-season cropping (Kpadonou *et al*., 2012). Cropping dykes in the Ouémé Valley [1.3.1e] of Benin are the strip of land that surrounds the agro-finger ponds. It is the earlier emergence of soil collected to create the finger pond. The dykes are covered with mulching for holding water and reducing soil moisture loss (Kpadonou *et al*., 2012).

Farmers in the northern part of Ghana [1.3.1f] generally cultivate large tracts of land as a form of insurance in case there is crop failure (Yaro, 2010). Dry season gardening and compound farming have become significant, especially along the river beds and around homes of farmers generally using hand-dug wells. In the case of the community from the Sudan savannah [1.3.1g], some of the community members commute to the banks of the White Volta, which is about ten miles from the community. They cultivate vegetables like onions, tomatoes, okra, and aleefu, which give them a good source of income (*ibid*).

Soil and water management in America

Farmers in the southern area of St Elizabeth [1.3.2a], one of Jamaica's largest parish, produces large quantities of Guinea grass (*Panicum maximum*) despite being the driest parish of the island (Simpson, 2010). The adaptability of Guinea grass, a perennial tufted grass, to tropical climate drought-like conditions and a variety of soil types makes it suitable fodder for local livestock. The grass is cultivated as a mulch crop, and this is either transported to the planting area or used in situ after cutting. Crop plants are introduced directly into plant holes which are dug through the mulch material. There is limited irrigation during crop growth and the mulch helps to protect soil water which is obtained from rainfall. These

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cultural practices were established as a result of the dry conditions and produce economically acceptable yields in the area.

In Mexico [1.3.2b], farmers and agricultural organisations, apply silvopastoral practices. This is the integration of trees with forage and livestock production (Pagiola *et al*., 2004). Silvopastoral practices are used to overcome cattle production systems, providing deep root systems and dense perennial vegetation. Plantation of trees and shrubs with high densities in pastures provide shade and diet supplements as well as soil protection from erosion and packing. Increasing plant diversity helped in the maintenance or improvement of pasture productivity by expanding nutrient recycling and production diversification. Silvopastoral practices fixed large amounts of carbon in the soil and tree biomass.

Communities near the Xochimilco-Chalco Lake [1.3.2c] in the Mexico City used chinampas are raised platforms (floating gardens), which are narrow enough to supply water for growing crops in shallow-land zones (Altieri and Koohafkan, 2008). It is Mesoamerican agriculture which used small, rectangular areas of fertile arable land to grow crops on the shallow lake beds). Chinampas are very useful during the dry season when lake levels fall below the rooting zone. The narrow canals allow the chinampero to irrigate from their canoes. Chinampas reduced soil erosion and increase water filtration towards the roots, reducing farmers' vulnerability to erratic rainfall. The soil platforms are continuously enriched with organic matter that is produced together with aquatic plants and sediments. In chinampas, the major source of organic matter comes from the water hyacinth (*Fichornia crassipes*), which is an aquatic plant native to South America. This plant is used as fodder/ forage/ animal feed, mulch as well for the removal of nutrients and toxic chemicals in water (Holm, 1997).

The Otomi ethnic group, in Mezquital Valley [1.3.2d] (Mexico), used Maguey (large agaves of Mexico and the southern US) to manage soil during the establishment of terraces to reduce soil erosion (Altieri and Toledo, 2005). Of the approximately 200 species in the Agave genus, several taxa have long benefited indigenous groups throughout the U.S. Southwest [1.3.2e], Mexico [1.3.2b], and Central America [1.3.2f] as food, beverages, sweetener, bioenergy, fibres for ropes and fabrics (Stewart, 2015).

Communities near Lake Titicaca [1.3.2g], on the border between Peru and Bolivia, use an ancestral technique known as the *waru-waru* (high beds), which promote draining, restrain flooding, and help to aerate the roots (Aguilar and Jacobsen, 2003). During dry periods, the *waru-waru* store enough moisture during dry periods (Saylor *et al*., 2017). This technique reduces the impact of extreme weather as it stores heat and maintains soil fertility, helping farmers adapt their agricultural production to current and future impacts of climate change.

The agro-ecological zone on the Peruvian Altiplano [1.3.2h] is large and complex, accommodating an adequate variability of agricultural production determined by specific physical factors (Aguilar and Jacobsen, 2003). The relief of the soil surface, soil type, and its hydric characteristics, are the main factors influencing the effects of exposure to climatic factors. The temperature varies in the different physiographic zones (upper part of the hill, slope, hill foot, crest, plain, and Lakeshore). The top of the hill or mountain is the coldest part, posing few possibilities for agricultural production. In each physiographic zones, communities grow the most appropriate plant cultivars. The slope areas are suitable for cultivation of a range of species, including potatoes and other Andean tubers (*oca, mashua*, and *ulluco*), seed crops (barley, wheat, rye, and field beans), and *quinoa* cultivars with low frost tolerance (white grains). In the highest situated agro-ecological zone of the Puna, the slope is the only cultivable area, with the only crop options being bitter potato, *cañiwa* (chenopodiumpallidicauleAellen), and *quinoa kcoitos*.

Cultural adaptations that farmers have developed in the Andes [1.3.2i] include (Altieri, 1996):

- domestication of a diversity of plants and animals and maintenance of a wide genetic resource base;
- establishment of diverse production zones along altitudinal and vertical gradients;
- development of a series of traditional technologies and land–use practices to deal with altitude,
- slope, extreme climates, etc;
- different levels and types of social control over production zones, including sectorial fallows.

In the Lake Pátzcuaro river basin [1.3.2j] in the state of Michoacán, Mexico, the Tarasco indigenous people cultivate corn using a range of land management

practices based on agricultural and climatic indicators, as well as local festivals. The knowledge includes a system for classifying and zoning agricultural land use based on the biological characteristics of different corn varieties (Chilon, 2008).

To manage native and wild agrobiodiversity, throughout the Andes [1.3.2i], there is a long tradition of agricultural practices that conserve the natural diversity of crops such as potato, quinoa grain, squash, and fruits. Traditional mountain communities possess a rich knowledge of the genetic characteristics and varieties of each native crop and its wild relatives. Using this knowledge, the communities apply selective breeding methods to increase the resilience of cultivated crops to variable environmental conditions brought about by global climate change (*ibid*).

Soil and water management in Asia

Conservation of soil and water resources is the most important feature of sustainable development. Soil erosion may cause severe loss of topsoil where organic matter and vital nutrients needed by the crop. Loss of organic matter and soil nutrients harm farmland's suitability for farming and reduces its ability to retain water. Indigenous peoples with a historical continuity of resource generally possess a broad knowledge base of the behaviour of complex ecological systems in their own localities.

Traditional farmers in the central Himalayan [1.3.3a] use various methods for soil and moisture conservation (Negi *et al*., 2003). In summer, farmers collect pine leaves and spread them over their paddy rice fields and burn them. The inflammable pine needles burn rapidly and consume the weeds and their seeds/ rootstock at the soil surface. Consequently, soil fertility is improved. Furthermore, farmers also gather and weeds and minor crops allow them to dry and they put them back to the crop fields because they believe that ash enhances soil fertility while burning controls weed infestation.

Himalayan farmers use flood water because it carries organic matter and humus along with it and deposits fine silts that increase soil fertility. Furthermore, they practice *in-situ* maturing in the crop field. The practice involves keeping livestock (cattle) overnight in the field for days after the *Kharif* crop harvest. When the dung and urine deposition on the fields is considered adequate the livestock is moved to other fields. Additionally, to minimize water needed for germination, these farmers use wet soils mixed with seeds of rye (*Brassica nigra*) placed inside the holes left between the stones of terrace risers (Negi *et al*., 2003).

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Irrigation in the Himalayan region [1.3.2a] is done through mud line canals (*kuhl* or *gul*), carved out of the hill slope along the gradient of gravity. Farmers, irrigate crops based on traditional knowledge. For instance in paddy fields, irrigation is done 7-8 times throughout the growing period when the normal water supply is available.

The Himalayan farmers also pave different ploughing method that conserves soil moisture. After the winter rains, crop fields are ploughed and compressed levelling is done using a heavy wooden plate. This practice conserves soil moisture in the deeper layers of the soil to obtain good seed germination. Fields are ploughed soon after crop harvest at the end of the rainy season. Additionally, in autumn when the fields are under fallow farmers' saturate them with water to avoid competition for water during the seedbed preparation. Seed sowing is also done in a circular way to raise paddy nursery, this technique is known in the region for conserving water compared to broadcasting sowing and line sowing(Negi *et al*., 2013).

Many regions South East of Asia, parts of Indonesia [1.3.3b], China [1.3.3c] (Longxian village of Zhejiang province [1.3.3d]) and the Philippines [1.3.3e] have transformed wet and humid lands into highly productive rice fields (Sharma *et al*., 2014). Rice is commonly cultivated engrossed in water and sometimes alongside edible fish. Farmers in these regions believe that cultivating rice next to edible fish keeps weeds that are potentially harmful to rice under control and simultaneously fertilizes the land in a natural way. Additionally, green manure, farmyard manure, *in-situ* such as by keeping sheep and goats, mulching , use of nitrogen-fixing plants, crop rotation, fallowing, terrace risers slicing, trapping flood water for fertigation, burning of trash use of forest and black soils, burying dead animals and mobile toilets are recognized as indigenous soil fertility management practices in Nepal [1.3.2f] (*Ibid*).

In the Gwallek–Keda (Baitadi district [1.3.3g], Nepal), farmers plant legume crops in paddy fields. They also intercrop soybean with maize and apply farmyard manure to improve soil fertility (Atreya *et al*., 2018).

In central Iran [1.3.3h] toward the east and southeast of Iran, underground drainage tunnels (*qanat*) are used. *Qanats* are built with a slight slope to guarantee a slow but constant flow of water that prevents erosion of the tunnel walls. Being about 1½ meter high and a ¾ meter wide, *qanats* are rather narrow, but they can reach depths of 30 meters (the record seems to be 60) and can cover distances of many kilometres. A *qanat* system consists of an underground part and a part above the ground surface. The underground part is separated into the water production section and the water transport section. In the water production section, water is collected either from a natural source or through infiltration of groundwater (Clarke, 1990).

Farmers in Nepal [1.3.2f] use traditional irrigation systems and have institutions that manage water distribution. These institutions regulate water use, based on socioeconomic circumstances and other stresses in the area (MOSTE [n.d]). Farmers use Sancho (a device cut from the tree trunk), in irrigation canals, to distribute water to the smaller canal that serves farming plots. Farmers also use bushes, wood, mud, and stones as Sancho (MOSTE [n.d]). These traditional methods can be seen in the Panchakanya Irrigation System in Chitwan District [1.3.3i] and Sorah-Chhatis Mauja Irrigation System in Rupandeh District [1.3.3j] of Nepal. Local people of Kathmandu [1.3.3k], Patan [1.3.3l] and Bhaktapur [1.3.3m] use *Dhunge dharas* and *Paani Pandheros* that tap natural springs (MOSTE [n.d]). *Dhunge Dhara* is a traditional stone water tap that originates from Nepal.

In the Chure region [1.3.3f], Nepal farmers plant *amriso* (bouquet grass) and *babiyo* (*Eulaliopis sp.*), species ton stabilize soil properties. Traditional communities in Nepal also plant bamboo species to conserve soil and control runoff in gullies and shady (MOSTE [n.d]).

Soil and water management in Oceania

Climate change directly affects the poor who are most dependent on the ecosystem services for their livelihood. Farmers, herders, and other poor households face many practical challenges such as severe drought and flooding, declining agricultural productivity and unsustainable production practice. The traditional knowledge base regarding, skills in and capacity for managing water for different uses have a long history among the communities of Asia.

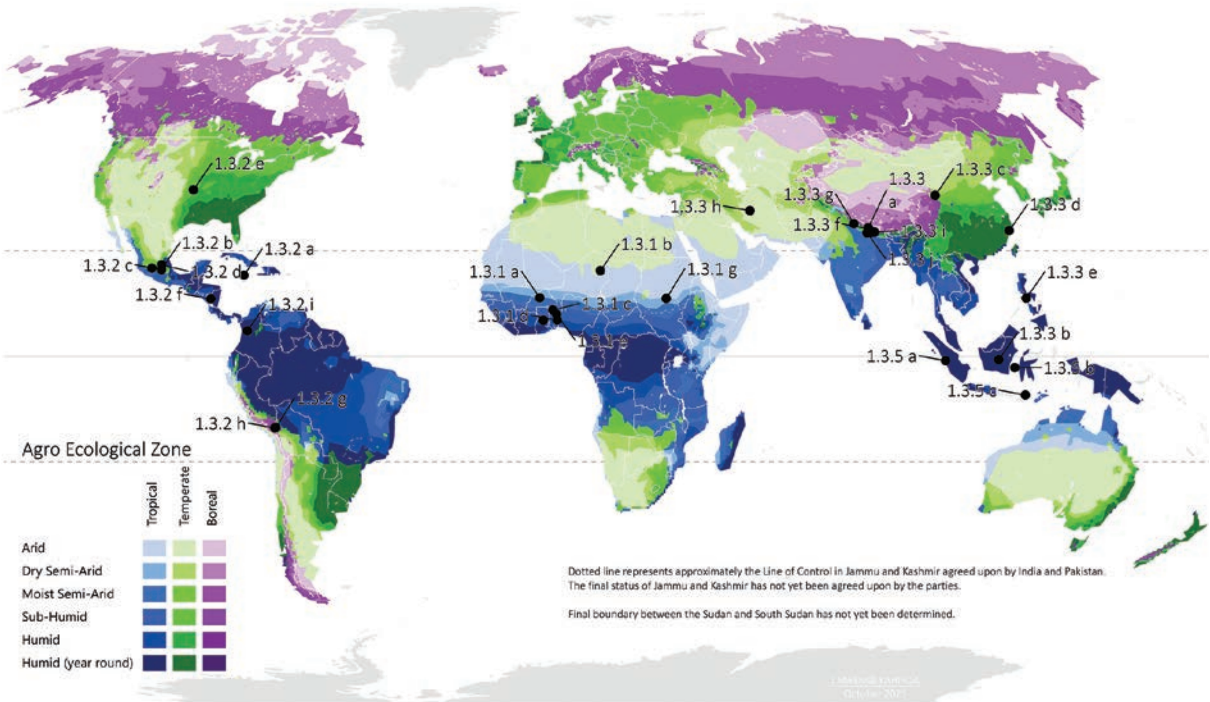
In West Sumatra [1.3.5a] Indonesia, water resources are controlled and regulated by custom. The traditional irrigation systems are managed by *ninik mamak* (indigenous elders), which are directly appointed

by *kapalo banda* (the headmaster of irrigation) to regulate water sharing during the night (David and Ploeger, 2014). Farmers have to keep to the prescribed schedule in order to water their field. In addition, the land has to be watered at night between 6 pm and 6 am and there should be no runoff from it. There are penalties for breaking the rules. Planting time is in accordance with the local understanding of the microclimate fluctuations (David and Ploeger, 2014). Knowledge of the seasonal changes plays a key role in temporal towards sustainable resource use such as rotation of traditional grazing by herders in West Sumatra, Indonesia.

To prevent coastal erosion in Aceh [1.3.5b], Indonesia the coastal forest is managed by the traditional fishermen organisation, several rows of different species of trees, bushes, smaller vegetation are planted along the shore to prevent and mitigate impact from high waves and strong winds (Hawasaki *et al*., 2014).

Farmers in East Nusa Tenggara [1.3.5c] (Indonesia), have several practices to improve soil fertility and prevent erosion, such as slash and burn cultivation on rotation basis, integration of trees into field, as well as building contour barriers from dry branches, shrubs, and bamboo (Langill and Landon, 1998).

Figure 4. Geographical locations of narrated soil and water management case studies



Source: World Bank, 2021 & Plevin *et al.*, 2014, modified to comply with UN Geospatial. 2021. *Map of the World*. Washington, DC, UN.

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TOPIC 1.4. WATER HARVESTING AND STORAGE PRACTICES

Rainwater harvesting (RWH) is a subdivision of water harvesting (WH) but, the two terms are used interchangeably (Mwenge Kahinda *et al*., 2011). The major categories of RWH when classified according to the use of the harvested water are: non-agricultural (residential, industrial and commercial) and agricultural RWH. While the former category encompasses harvest water from rooftops, terraces, courtyards and other impervious building surfaces for on-site use; the latter category encompasses subsistence, small-scale and commercial agriculture. The line is quite blurred, considering that some residential RWH systems, such as Polyvinyl chloride tanks, are used to water small vegetable gardens. RWH for agricultural use is further discretized according to the type of catchment surface used into in-situ RWH (iRWH) and ex-situ RWH (xRWH) and each has an array of techniques.

Ancient and traditional RWH technologies were either developed or started in response to the past climate change events, which included annual and multi-decadal fluctuation in precipitation patterns (Lucero *et al*. 2011; Pandey *et al*. 2003). Their subsequent decline has been mostly documented by historians and anthropologists (D'Souza, 2006). The complex array of factors responsible for either the decay, the disruption or the disappearance of traditional systems ranges from imperialism to incomplete understanding of local ecology, to disruptive social organisation introduced by colonialism. Although over the past four decades RWH is pioneered across the globe, RWH adoption rates are still low. Subsistence farmers are reluctant to invest time and money in setting up RWH structures, as they often have no security of land ownership and/or limited access to local markets where they could sell surpluses of food or cash crops (Drechsel *et al*., 2005). It is very difficult to distinguish between indigenous, indigenized and contemporary water harvesting systems. An indigenous system is those that were developed locally, indigenized systems, are hybrid solutions incorporating external influences, and finally, contemporary practices are those introduced more recently by scientists or development agencies (Denison and Wotshela, 2012).

Akpinar Ferrand and Cecunjanin (2014) identified fifteen major types of ancient and traditional RWH categories (Table 2) that were alike in practice and function despite the different climatic regions, in which they were found, or the cultures that practised them.

Table 2. Fifteen commonly practised ancient and traditional RWH strategies

RWH strategy	Description
(1) Pitting:	Pits are dug and planted with cultivars on flat or sloping surfaces. Pitting conserves soil moisture and increases groundwater recharge. Pitting will reduce the velocity of precipitation-engendered runoff if built along a contour.
(2) Contouring (stone/soil bunds, hedgerows, and vegetation barriers):	Contouring involves stone or earthen banks along a contour in a cultivated hill-slope. Hedgerows typically involve vegetation planted along a contour or cross-slope barriers of grasses and herbs. Contouring helps retain soil moisture, reduce soil erosion, and shorten slope length.
(3) Terracing:	Bunds in association with a trench along a contour on a sloping surface. Terracing helps reduce the velocity of runoff during precipitation events, conserve soil moisture, and reduce erosion.
(4) Micro-basins:	Different shapes of small basins, surrounded by stone or earth bunds to infiltrate precipitation related runoff.
(5) Pit courtyards:	Pit courtyards act as an impluvium to capture rainwater, surrounded by walls and impervious surfaces.
(6) In situ RWH:	Designed for increasing rainfall infiltration and reducing soil evaporation through practices such as ridging, mulching, broad bed and furrowing, hoeing, and conservation tillage.
(7) Rooftop RWH:	From rooftops, water is collected and stored in storage tanks built in courtyards of houses.
(8) Traditional open ponds:	Precipitation and runoff are collected in open ponds through a catchment system. Ponds may or may not have a lining. The absence of lining may lead to seepage.
(9) Cisterns:	Runoff collected and stored in underground storage reservoirs. Ancient cisterns may range from natural or excavated depressions in solid rock to lined structures.
(10) Micro-dams:	A stored and regulated flow of rainwater runoff for infiltration behind stone/earthen banks in a landscape with a gradient. Some micro-dam surfaces are planted after drainage to utilize silt deposition and higher soil moisture.
(11) Shallow wells:	Shallow wells dug in low depressions or ponds to collect surface runoff after percolation to extract water during the dry season.
(12) Underground well systems:	A proximate horizontal channel network or gallery excavated into an alluvial fan aquifer at the base of a mountain or foothill, recharged by precipitation.
(13) Runoff diversion and spate irrigation:	Diversion and spread of seasonal floods to agricultural plots from discrete rainfall events. These kinds of systems can be connected to terraces, reservoir systems, and dams of different sizes.
(14) Dams:	A stored and regulated flow of rainwater, runoff, and ephemeral streams behind large storage systems that are constructed around footslope of the hill.
(15) Large reservoirs/ lakes:	Precipitation and runoff collection in large-scale human-made basins

Furthermore, utilising the common RWH categories identified in (Table 2), Akpinar Ferrand and Cecunjanin (2014) identified and listed a good number of ancient and traditional societies that practised them (Table 3).

Table 3. Ancient and traditional RWH practices from semi-tropics (dry-wet), semi-arid, Mediterranean, and arid regions

RWH techniques	Semi-tropics (5 and 10 and 23.5°)	Semi-arid Mediterranean (20–45°)	Arid (20–45°)
(1) Pitting	1. Planting pits, Easter Island	1. *Zai* Pits, Eastern, Western, and Southern Africa. 2. Pitting, NE Iran. 3. Planting pits, ancient China	1. Ancient planting pits (utilizing mostly fog moisture), Atacama Desert, Peru. 2. Planting pits, North Africa
(2) Contouring (e.g. stone/ soil bunds, hedgerows, and vegetation barriers)	1. Contour farming systems, East and West Africa. 2. Southeast Asia.	1. Metlepantli or bordos contour terracing in Pre-Columbian and Colonial Mexico. 2. East and South Africa. 3. Traditional use of contour bunds, NE and NW Iran. 4. Ancient and traditional use of contouring, Central Asia. 5. Vegetable fibre contours, China.	1. Ancient and traditional use of contouring, American SW. 2. Ancient use of contouring, Negev Desert, Israel. 3. Tera systems, SE Sudan. 4. Ancient and traditional use of contouring, Yemen. 5. Sailabas and Khuskaba systems, Baluchistan
(3) Terracing	1. Ancient Maya contour terracing, Central America. 2. Ancient and traditional use of terracing in conjunction with other RWH systems, Southeast Asia.	1. Contour and cross-drainage dry farming lama-bordo terraces, west-central Oaxaca, Mexico. 2. Terracing in Andean Highlands, South America. 3. East Africa fanya juu terraces. 4. Traditional use of terraces, NE and NW Iran. 5. Terraces in semi-arid Yemen. 6. Khuls, rock terraces, India and Pakistan. 7. Ancient and traditional use of terraces, China.	1. Pre-Columbian terrace systems, Northern and arid parts of Mexico. 2. Ancient and traditional American SW terraces. 3. Terrace systems, Lanzarote, Canary Islands. 4. Jessour and Tabia, terraced wadi systems, Tunisia. 5. Ancient Roman wadi terracing systems, North Africa. 6. 6. Phonecian, Nabatean, Roman, Byzantine terraced fields, Near East.
(4) Micro-basins	1. Ancient Maya, box terraces/ gardens, Central America.	1. Pre-Columbian and Colonial bordered gardens, Mexico. 2. Negarims half-moons and eyebrows, East Africa. 3. Micro-basins, Mediterranean Antiquity. 4. Micro-basins, NE Iran.	1. Ancient and traditional American SW, waffle and grid gardens. 2. Micro-basins (e.g. half-moons), Canary Islands. 3. Micro-basins, West Africa. 4. Karm rock-wall gardens, Egypt.
(5) Pit courtyards		1. Pit courtyards, Mediterranean Antiquity. 2. Pit courtyards, Matera, Italy.	1. Chaco Canyon, Ancestral Pueblo pit courtyards. 2. North African traditional pit courtyards. 3. Pit courtyards, Petra, Jordan.
(6) In situ RWH (e.g. ridging, mulching, hoeing, broad bed and furrowing, and conservation tillage).	1. Ancient Maya bajo in situ RWH cultivation, Central America. 2. Easter Island, Rapa Nui, lithic mulching. 3. India traditional Vertisol ridging. 4. Ancient and traditional in situ RWH agricultural practices, Southeast Asia.	1. Ancient various in situ RWH practices, NW Argentina. 2. Lithic mulching, Mediterranean Antiquity. 3. Traditional Vertisol broad bed and furrow systems, Ethiopia. 4. In situ RWH practices, Central Asia. 5. Lithic mulching, China.	1. Rock/gravel mulching ancient and traditional American SW. 2. Historic use of ash and cinder mulching, Lanzarote, Canary Islands. 3. Nabatean and Sabatean in situ RWH practices, Israel. 4. Traditional in situ RWH practices, Sub-Saharan Africa. 5. Ancient and traditional in situ RWH practices, Yemen.

RWH techniques	Semi-tropics (5 and 10 and 23.5°)	Semi-arid Mediterranean (20–45°)	Arid (20–45°)
(7) Rooftop RWH	1. Tankas, India. 2. Motkas and Kalshi rooftop RWH, Bangladesh. 3. Traditional rooftop RWH practices in Kenya, Indonesia, Thailand, Vietnam, and Southern China.	1. Colonial rooftop RWH practices, Mexico. 2. Traditional use of rooftop RWH, NE Brazil. 3. Antiquity rooftop catchment systems, Mediterranean. 4. PVC and Djabir tanks, Sub-Saharan Africa. 5. Traditional jar/clay pot rooftop RWH, Gansu, China	1. Traditional rooftop RWH practices, Canary Islands. 2. Traditional rooftop RWH, North Africa (Soufirs/ Tkhabit, Algeria)
(8) Traditional open ponds/ reservoirs (0–20 000m^3)	1. Ancient Maya aguadas (ponds), Central America. 2. Trapeang tanks and rural ponds, Angkor Wat, Cambodia. 3. Jheels tanks, Western Coastal Plain, India. 4. Kohli tanks, Maharashtra, India. 5. Wewa reservoirs, Sri Lanka. 6. Telaga ponds, Indonesia. 7. Traditional use of ponds, Thailand. 8. Tameike ponds in Japan. 9. Traditional ponds, Taiwan. 10. Ifugao ponds, Philippines. 11. Aquacultural ponds, China.	1. Pre-Columbian reservoir systems, Mexico. 2. Caxias ponds, semi-arid Brazil. 3. Tiwanaku artificial qochas ponds, South America. 4. Albercone ponds, Canary Islands. 5. Traditional use of ponds in East Africa and Southern Africa. 6. Laghi ponds, Italy. 7. Gol farm ponds, NE and NW Iran. 8. Chandela, Bundela, and Pokhariyan tanks/ponds, India. 9. Ponds in semi-arid China. 10. Reservoirs, Indus Valley civilization. 11. Reservoirs of Chosun/ Joseon Dynasty, Korea.	1. Ancient and traditional reservoirs with associated drainage channels, American SW (e.g. Papago balsas; Hohokam reservoirs). 2. Mareta reservoirs, Lanzarote, Canary Islands. 3. Lac collinaires, Algeria. 4. Hafirs of Sahel, Eastern Africa. 5. Ancient reservoir system, Jawa, Jordan. 6. Ancient reservoirs, Yemen. 7. Nadis (village ponds), Rajasthan, India
(9) Cisterns	1. Ancient Maya chultunes, subterranean water storage pits.	1. Pozos cuadrados, walk-in wells, Tehuacan Valley, Mexico. 2. Cisterns of semi-arid NE Brazil. 3. Phonecian, Carthaginian, Hellenistic, Ancient Roman, and Byzantinian cisterns of Mediterranean Antiquity. 4. Hittite, Urartu, and Ottoman cisterns, Turkey. 5. Ab Anbar cisterns, Iran. 6. Clay lined water cellars of Shanxi, Shanxi, and Gansu provinces of China.	1. Aljibe household cisterns, Canary Islands. 2. Ancient Israel/Palestine cisterns. 3. Nabatean cisterns, Near East. 4. Ancient and traditional use of cisterns, North and Sub-Saharan Africa. 5. Ancient cistern use, Arabian Peninsula. 6. Step-wells of Western India. 7. Kunds and Tankas of Western India. 8. Shuijiao cisterns, China.
(10) Micro-dams (earth dams)		1. Sand dams, Andean Highlands. 2. Murumdum high earth banks, Brazil. 3. East Africa and Southern Afric. 4. Bandsar system, NE Iran. 5. Ahar systems, Bihar, India. 6. Johad and Rapats, Rajasthan, India. 7. Liman high banks and Khaki system, Central Asia. 8. Ancient China	1. Trinchera rock curtains, Northern Mexico. 2. Ancient Egypt. 3. Meskat and manka systems, Tunisia. 4. Khadins (dhora), Western Rajasthan, India.

RWH techniques	Semi-tropics (5 and 10 and 23.5°)	Semi-arid Mediterranean (20–45°)	Arid (20–45°)
(11) Shallow Wells	1. Buk'te, casimba shallow wells in ponds, Ancient Maya. 2. Virdas shallow wells dug in low depressions, Western Coastal Plain, India. 3. Round or square shallow wells of Wendeng and Shandong provinces, China.	1. Virdas, Gujarat, India. 2. Pit-like shallow wells dug into Laghi lakes, Italy.	1. Shallow wells built in the beds of ravines, Lanzarote, Canary Islands. 2. Kuis/Beris deep pits dug near tanks, to utilize seepage, Western Rajasthan, India
(12) Under-ground wells.	1. Sarangams, SW India.	1. Galerias, Spain/Mexico. 2. Urartu, Seljuk, Ottoman period galleries, Turkey. 3. Qanat and Karez systems, Western and Central Asia.	1. Nazca Puquios shallow underground wells, Peru and Northern Chile. 2. Foggara, North Africa 3. Aflaj/Falaj, Arabian Peninsula. 4. Karez, Central Asia. 5. Paar systems, Western Rajasthan, India. 6. Karez, Xinjiang, China
(13) Runoff diversion and spate irrigation.	1. Canal and pond runoff diversion systems, ancient Maya, Central America. 2. Inundation channels in connection to tanks/ponds/lakes, Bengal, India. 3. Katas/Mundas/Bandhas irrigation system Madhya Pradesh, India. 4. Korambu diversion system, Eastern Ghats, India.	1. Pre-Columbian and Colonial runoff diversion systems, Mexico. 2. Ancient and traditional runoff diversion systems and spate irrigation, Andes, South America. 3. East Africa (e.g. Ethiopia and Kenya). 4. Dasht ephemeral stream diversion and spate irrigation systems, NE and NW Iran. 5. Pat water diversion system; Naada/Bandha stone check dam systems, India. 6. Ancient China.	1. Ancient and traditional systems, American SW. 2. Pre-Columbian runoff diversion systems, Mexico. 3. Moche IV and Inca Empire, Peru. 4. Ancient and traditional runoff diversion systems, Southern Canary Islands
(14) Dams	1. Palace Dam in Tikal, Guatemala.	1. Purron Dam Complex in Tehuacan Valley. 2. Hittite and Urartu dams, Anatolia, Turkey.	1. Ancient Roman dam, Libya. 2. Esseed. dams, Algeria. 3. Ancient dam in Jawa, Jordan. 4. Marib Dam, Yemen
(15) Large reservoirs	1. Large-scale reservoirs of ancient Maya. 2. Barays of Angkor Wat, Cambodia. 3. Sagar lakes in India. 4. Large tanks, Burma. 5. Largescale reservoirs, Sri Lanka. 6. Large tanks, Eastern Java.	1. Talab and Sagar/Samand lakes, Central Highlands, India. 2. Large-scale reservoir systems of the Baekje Dynasty, Korea.	1. Large-scale reservoirs, ancient Yemen

There is a difference between a conventional dam and an RWH storage system. RWH storage dams get their water from undefined drainage networks; the water collected is used for supplemental irrigation and their storage capacity does not exceed 0.5 Mm^3 (Mwenge Kahinda *et al*., 2007).

Water harvesting in Africa

In many parts of Burkina Faso (Yatenga region [1.4.1a]) and Mali (Dogon Plateau region [1.4.1b]), there has been a re-establishment of the old water harvesting system known as *zai*. The *zai* are pits that farmers dig in a rock-hard barren land, into which water penetrates (Altieri and Koohafkan, 2008). Farmers have shown interest in the *zai* system as they notice that the pits efficiently accumulate and concentrate runoff water and function with small quantities of manure and compost. The practice of *zai* allows farmers to expand their resource base and to increase household security.

In northern Burkina Faso [1.4.1c], Sahelian community, farmers have adopted several soil conservation practices, such as stone bounds, the *zai* and composting and manuring techniques. These local methods have helped them reduce their crop and livestock vulnerability to climate variability. According to farmers, most of the new techniques have been adopted because of growing land shortage and new market opportunities, rather than because of climate variability.

Zai planting method has been employed by traditional farmers across Burkina Faso [1.4.1c] and other countries through what is called the *Zai* model (Ouedraogo and Sawadogo, 2001). There are three different styles or models in training farmers in the use of the *zai* method: The *zai* market day-model where farmers come from different places to see and learn the *zai* method, the material and tools used. Secondly, through the *zai* school-model, this is where farmers dedicate themselves to teach groups of farmers in the making and use of the *zai* strategy. And, the *zai* teacher-student model, this is where an experienced farmer goes from village to village and teach individual farmers to make *zai*. The students are then required to transfer this knowledge (Ouedraogo and Sawadogo, 2001).

There are several indigenous water harvesting systems in North Africa. In fact, the dry areas of West Asia and North Africa (WANA) are very rich in traditional, ancient water-harvesting systems that were built on a sound foundation of indigenous knowledge (Oweis *et al*., 2004).

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Water harvesting in America

Communities in Mexico [1.4.2a], Bolivia [1.4.2b] and Peru [1.4.2c], use rainwater harvesting practices together with traditional agro-ecological methods, *q'otañas* (form of rainwater harvesting using clay layers of soil), *q'ochas* (superficial depression that stores water), and *waru-warus* (raised fields that have canals surrounded by ditches that are filled with water) (Zavala *et al*., 2018). These practices improve the local supply of water, as it enhances soil infiltration, as well as enhances biomass production as it is structured to trap sediments (Wilk and Wittgren, 2009).

The Otomi community [1.4.2d] of Mexico builds *bordos* (small tank like rainwater harvesting and storage structure) for trapping rainwater on hillsides. Bordos are placed along contours together with stones and maguey plants (*Asparagaceae*) to store rainwater for irrigation and reduce erosion (Altieri *et al*., 2005).

On hills, ditches and trenches are used to store water. On gradual inclines, borders, terraces, earth dykes, and watering holes are built, making it easier to irrigate crops as well as water cattle (Altieri and Koohafkan, 2008). Terraces were structured in such a way that they absorbed heat during the day time and released it during the night, this creates warmer micro-climate that preserve crops from frosts, extending the growing season of crops and crop diversification (Clements *et al*., 2011).

In Mexico [1.4.2a], the *Cajete* Terrace agro-ecosystems have been in place for 3 000 years in hillside regions in Tlaxca [1.4.2e] (de la Torre *et al*., 2010). In these rainfed, corn-bean-squash agro-ecosystems, food is grown on steep, erosion-prone slopes. Rainfall is concentrated between May and September and often occurs in sudden downpours. Sloping terraces feed excess water into *cajetes* (underground tanks) and slowly percolates into the surrounding soil after the rain has ended. Eroded soil is also trapped into the *cajetes*, preventing soil loss down the slopes. Nutrients rich soil inside the *cajetes* is later gathered and distributed into the field.

The terraces throughout the Andean slopes [1.4.2f], and the *waru-waru* (raised fields) and *qochas* (excavated pits) in the Altiplano [1.4.2g] are examples of successful adaptation to difficult environments by indigenous farmers (Altieri, 1996). These systems are productive, sustainable, ecologically sound, and tuned to the social, economic, and cultural features of the Andean heterogeneous landscape.

The Aymaran indigenous people of Bolivia [1.4.2b] have been coping with droughts through the construction of small dams called *"qhuthañas"* (de la Torre *et al*., 2010). These dams collect and store from 50 to 10 000 m^3 of rainwater. Predictions on the intensity of the droughts are based on the knowledge and observations of the *"yatiris"* (wise men or advisers).

Water harvesting in Asia

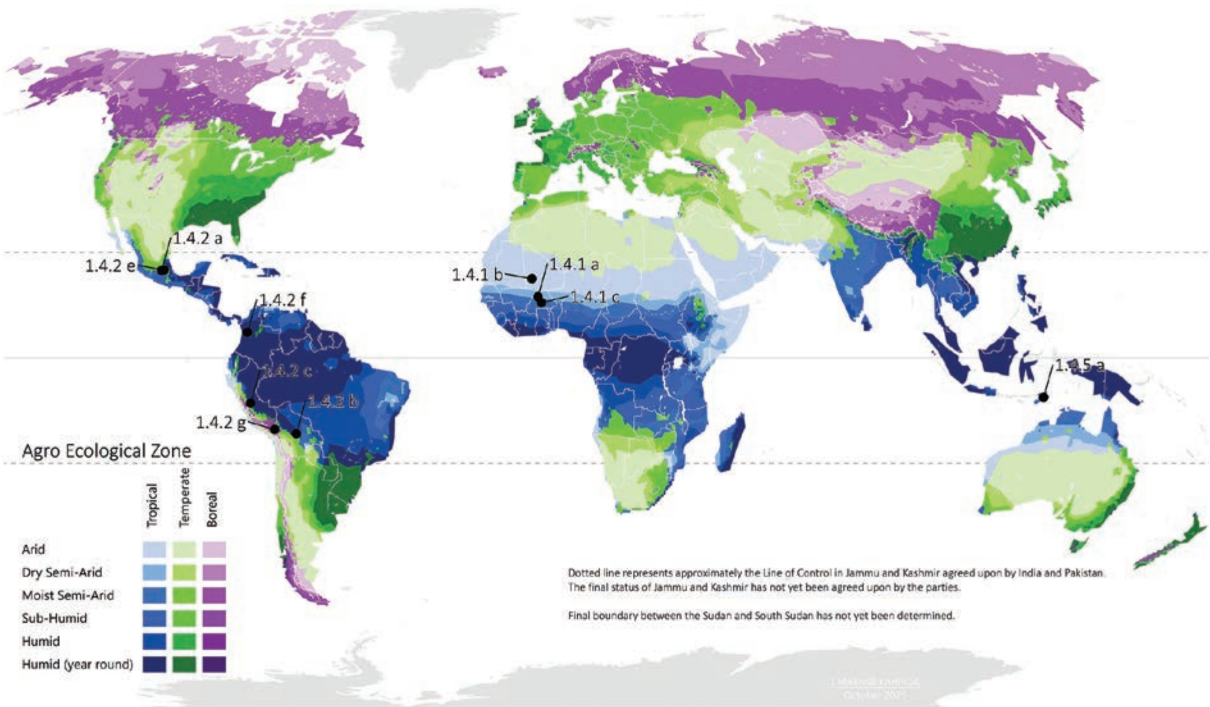
While it is difficult to trace the origin of RWH, scholars believe that the various techniques were independently invented in different parts of Asia (Mwenge Kahinda, 2013):

- About 7000 BCE, in southern Jordan, early structures were constructed (Oweis *et al*., 2001);
- Around 4500 BCE, in southern Mesopotamia, RWH systems were used (Falkenmark *et al*. 2001; Oweis *et al*., 2001);
- 5 000 years ago, in Iraq in the so-called Fertile Crescent regarded as the cradle of agriculture, RWH techniques were used (SIWI, 2001);
- Evidence of RWH used 4 000 years ago or more are present in the Negev desert of Israel (Evenari *et al*., 1971);
- More than 4 000 years ago, in India and China, RWH was in use (SIWI, 2001);
- Some 100 years BCE, throughout the Mediterranean and the Middle East, RWH was already a common technique (Smet and Moriarty, 2001);
- 2 000 years ago, in the loess plateau of China -Ganzu Province, rainwater was collected in wells and jars (Gnadlinger, 2000).

Water harvesting in Oceania

In Timor-Leste [1.4.5a], local communities dig small holes (*be'e matan/ posu"*) next to the river bed to collect clean water. The water seeps through the sand and wells up through the soil. Many communities in rural areas still continue to use this practice to access clean water during wet and dry seasons in their efforts to adapt to climate change (Pinto, 2014).

Figure 5. Geographical locations of narrated water harvesting case studies not listed in the tables



Source: World Bank, 2021 & Plevin *et al.*, 2014, modified to comply with UN Geospatial. 2021. *Map of the World*. Washington, DC, UN.

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TOPIC 1.5. AGROFORESTRY MANAGEMENT AS A COPING STRATEGY FOR WATER SCARCITY.

Several guidelines can be used to classify and group agroforestry systems (and practices). The most commonly used ones are the system's structure (composition and arrangement of components), its function, its socio-economic scale and level of management, and its ecological spread (Nair, 1985). Structurally, the system can be grouped as agrisilviculture (crops - including tree/shrub crops - and trees), silvopastoral (pasture/animals + trees), and agrosilvopastoral (crops + pasture/animals + trees).

Agroforestry management in Africa

In Africa [1.5.1a], farmers have conserved and incorporated trees in their landscapes. Traditionally farmers grow crops under scattered trees of different species. Some of the agroforestry practices that are being implemented by the rural communities in Africa include: rotational woodlots (Kalabe *et al*., 2010; Cook and Grut, 1989), improved fallows (Cook and Grut, 1989), indigenous fruit trees in the parkland system (Boffa, 2000; Chitakira and Torquebiau, 2010; Cook and Grout, 1989; and Kalabe *et al*., 2010; Mbow *et al*., 2014), *taungya* systems (DAFF, 2017; Steppler and Nair, 1987), home gardens (Cook and Grut, 1989), tree crops and shade trees (Cook and Grut, 1989), Savannah grazing (Cook and Grut, 1989), silvopastoral systems (Msuya and Kideghesho, 2012), and live fence-posts and windbreaks (Steppler and Nair, 1987).

Woodlots have been encouraged in densely populated areas in Africa [1.5.1a] where natural fuelwood supplies have nearly disappeared. They are one of the agroforestry options with the potential to arrest deforestation and shortage of wood fuel energy in Southern Africa [1.5.1b] (Kalabe *et al*., 2010). Woodlots are tree stands planted on farms, communal land or degraded lands to provide products and services, as they promote biodiversity conservation and reduce deforestation.

In Zambia [1.5.1c] the rural households intentionally preserve fruit trees on their fields when practising parkland systems in agricultural land (Kalabe *et al*., 2010). Similar cases have been observed in Malawi [1.5.1d] where during woodland clearing before cultivation of settlement, predominant fruit trees (*Parinari curatelilifolia, Strychnos cocculoides*, and *Uapaca kirkina*) are customarily left uncut and scattered around homesteads or crop fields as well as in Tanzania [1.5.1e], Zambia [1.5.1c] and Zimbabwe [1.5.1f] whereby *Parinari curatelilifolia* and *Uapaca kirkina*

are left in cultivated fields (Kalabe *et al*., 2010). This practice increase crop yields, income and savings resulting in the change of wealth and soil improvements.

Agroforestry parklands display that they are rational land use systems developed by farmers over many generations to diversify production for livelihood, income generation and the minimization of environmental risks related to high climate variability.

The open woodlands are known as savannah cover an area of approximately 103 billion ha in Africa (Cook and Grut, 1989). The savannahs are predominantly situated in the north and south of the equilateral rainforest belt. In Sahel [1.5.1g], one-third of the forage is produced by trees and shrubs. Camels and goats obtain much of their food from these sources. In the drier regions of the savannahs, *Acacia Senegal* (gum Arabic tree) is one of the important trees. This tree produces pods and leaf fodder for livestock, fibre, and wood. The tree improves the soil through its capacity to fix nitrogen, as well as useful for windbreaks in Sudan [1.5.1h]. This species is thus further classified as a silvopastoral species. Hence, it can also be planted in agricultural areas, where it can be intercropped. *Acacia tortilis* is another species used by farmers in Africa to feed livestock and wildlife. It is a drought resistant species that provides wood and animal feed.

In the Guinea type savannah in northern Ghana [1.5.1i], shea butter (*Butyrospermum parkii*) and the West African locust bean/ *dawadawa* (*Parika clappertoniana*) are the most important trees in farmed parklands (Cook and Grut, 1989). Shea butter is important in the local diet, used as medicine, in cosmetics, soaps, and cooking. The tree has a narrow Crown, allowing the tree not to provide much shade on the crops around it. The *dawadawa* tree is a leguminous, nitrogen-fixing tree which improves the soil.

In drier Sudan [1.5.1h] type trees (*Acacia albida*, also known as *Faidherbias/ Gao*) are planted in West Africa, Sahel as well as in Malawi as a soil improver (Cook and Grut, 1989).

The Australian species *Grevillea robusta* ("silky oak" of "silver oak") was introduced as a shade tree planted in the coffee plantations of East Africa [1.5.1j] (Cook and Grut, 1989). Farmers appreciate this species and use its leaves for mulching.

Swidden agriculture is the traditional form of shifting cultivation in Africa [1.5.1a]. In Comoros, farmers use

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Cajanus cajan or pigeon pea to preserve and enhance soil fertility (Cook and Grut, 1989). Pigeon pea is a nitrogen-fixing woody shrub which has the capacity to grow on very poor soils and in very dry climates. Pigeon pea protects and enhances the soil. Its woody stalks are used for fuel, the peas for food and pods and foliage for feed.

In Africa [1.5.1a] forests are reduced but the number of trees planted on the farms is increased. Therefore there is an increase in spontaneous agroforestry. This is most evident in the densely populated highlands of East Africa, in Kenya [1.5.1k], Rwanda [1.5.1l] and Burundi [1.5.1m]. Farmers plant trees for fuelwood, building poles, fruits, shade, fencing, timber, fodder, soil improvement and protection against wind.

In east Africa [1.5.1j] an initiative was approached whereby dairy farmers grew fodder shrubs as supplementary feed. In Central Kenya [1.5.1k] dairy farmers planted shrubs (*Calliandra calothyrus* and *Leucaena trichandria*) to feed their dairy herds (Daff, 2017), increasing milk production. In the Philippines, farmers grew a combination of improved fodder grass and trees (*Gliricidia sepium*) and this assisted them in improving their livestock and crop production.

Traditional agroforestry systems practised in Tanzania [1.5.1e] are the *Chagga* home gardens (involves the combination of several multi-purpose trees and shrubs with food and cash crops and livestock occupying the same unit of land) in the northeastern Tanzania [1.5.1e], the *Kagera* in the home gardens of the Mara regions [1.5.1n] in northwestern Tanzania, the *Usambara* (intercropping cardamom (*Elettaria cardamomum*) and black pepper (*Piper nigrum*) with trees, especially with Grevillea robusta) a traditional system in northeastern Tanzania [1.5.1e], and the traditional *wasukuma* silvopastoral system called *"nigitili"* in western Tanzania [1.5.1e] (Msuya and Kideghesho, 2012). These agroforestry systems use multi-layered systems with a combination of annual and perennial plants, which imitate natural ecosystem (Msuya and Kideghesho, 2012).

The northern regions of Uganda from the parishes in Apac district [1.5.1o] farmers planted eucalyptus species in swamps to reduce flooding.

Alley cropping is practised in humid lowlands as well as in sub-humid to semi-arid zones like Machakos [1.5.1p] in Kenya (Okullo *et al*., 2003).

Agroforestry management in America

The practice of combining trees with pastures is widespread in various climatic zones throughout Central America [1.5.2a], particularly in the wet lowlands, lowlands with prominent dry season and highlands (Steppler and Nair, 1987). In the Central American regions [1.5.2a] mainly in lowland pasture with high rainfall, fostering of natural regeneration of *Cordia alliodora* was practised (Budowski, 1993). Species which has high commercial value for its timber. This practice, is mainly observed in Costa Rica [1.5.2b], Panama [1.5.2c], Nicaragua [1.5.2d], Honduras [1.5.2e] and Guatemala [1.5.2f]. It has also been observed in Tabasco [1.5.2g] (Mexico) and evident in the Amazon region of Ecuador [1.5.2h], notably the Coca area. *Cordia alliodora* is a sun-loving species that self- prunes and has a straight trunk with a small Crown, permitting light penetration (Budowski, 1993).

In Costa Rica [1.5.2b] living fence-posts, mainly made of *Gliricidia sepium*, are used to fence-off pasture and crops. *Gliricidia sepium* is a medium-sized tree that grows 10 to 12 meters high. It is used for many other purposes including fodder, firewood, and green manure and intercropping. Furthermore, it provides edible fruits and flowers, reducing the stress on natural forests (Budowski, 1993).

In El Salvador [1.5.2i] some farmers have replaced traditional crops with *Gliricidia sepium* fallow (Kass and Somaribba, 1999). Every five to ten years, the trees are harvested for fuelwood, the area is burnt and used for other crops.

In the southern part of the department of Lempira (western Honduras [1.5.2e]), farmers use the *Quezungual* systems (Hellin, 1999). The system consists of naturally regenerated and pollarded shrubs and trees in relation with more traditional agroforestry components such as high-value timber and fruit trees. Plots of the system consists of three levels: trees (*Byrsonima crassifolia* (nance), *P. guajava* (*guayab*), *C. alliodora* (laurel) and *Diphysa robinioides* (guachipilin)), pollarded trees and shrubs (*Citrus spp* (manderina), *Persea Americana* (Avocado), *Simarouba glauca* (Aceituno) and *Cedrela odorata* (Spanish cedar)), and agricultural crops (*Zea mays, Sorghum bicolour* and *Phaseolus vulgaris*) (Hellin, 1999). The system is largely linked with smallholder farmers, and common on slopes of 10 to 25 percent. Honduras [1.5.2e] experiences two harvests per rainy season

(Hellin, 1999). The *primera* (crops planted in April/ May and harvested in August/ September) and *postrera* (crops planted in August/ September and harvested in December. Farmers plant maize in the *primera* and beans in the *postrera*. Some farmers do not include the *primera* harvest and only cultivate in the *postrera* harvest to reduce the occurrence of pests and diseases. When farmers use the Quezungual system they do not burn their fields before planting. Vegetation is cleared by hand. The density of the trees and shrubs is managed ensuring that there is optimum shade for the agricultural crops and species are pollarded when crops are planted in the *primera* harvest and pruned in the *postrera* harvest. The pollarded and pruned material is spread throughout the plot as mulch and at times used as a fence.

Mimosa tenuiflora (carbon negro), a perennial tree or shrub native to the north-eastern region of Brazil, is used in Honduras [1.5.2e] in zones up to 1 200 m elevation with 600 to 1 500 mm rainfall per year with dry periods that last up to eight months (Kass and Somaribba, 1999). This tree is also used in Guatemala [1.5.2e]. El Salvador [1.5.2i], Nicaragua [1.5.2d] and Brazil [1.5.2j] in agroforestry systems. During the fallow periods, M tenuiflora is used for fuelwood, fence-posts, charcoal production and cattle grazing during the dry season. Maize and sorghum are cropped after the fallow (Kass and Somaribba, 1999).

Traditional agroforestry systems practised in North America [1.5.2k] include grazing in forests of the western United States [1.5.2m] (US), forest plantations of the southern United States (US) and alley cropping intercropping/ multi-cropping) with black walnut (*Juglans nigra L.*) in the Central US [1.5.2a] (Schultz *et al*., 1995) and Midwestern [1.5.2k] and southern US [1.5.2k] (Garret and Buck, 1997). Tree rows in this system are spaced in order to consider the biological needs of intercrops.

Closer within row spacing's supply greater protection of the site (e.g. erosion control) early in the rotation period. *Silvopasturing* is also common practice in the state of Washington, southern and west parts of the United States (US) and has considerable potential in the Midwest regions of the US (Garret and Buck, 1997).

Windbreak systems (Shelterbelts) are the oldest form of agroforestry in the US [1.5.2m]. This system is being practised in the northern, mid-western plains states (Kansas [1.5.2n], Nebraska [1.5.2o] and Dakotas [1.5.2p]) and western states where they are used

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for stabilizing microenvironments. Well-designed windbreak systems result in increased crop and livestock productions, reduce wind erosion, improves microclimates, snow retention and reduced crop damage by high winds. These systems are designed either as single or combined rows scattered across an area with spacing within the row that provide sufficient air movement, minimizing turbulence.

Kekchi Maya farmers in Belize [1.5.2q] use *Tapado* systems with crops (Kass and Somaribba, 1999). Farmers produce maize by traditional slash-and-burn systems and by a *malahambre* slash-mulch system on fertile soils along riverbanks. Similar combinations of these two systems are practised by farmers as they transfer from wetter to drier areas in Panama [1.5.2c] and the Amazon [1.5.2r] (Kass and Somaribba, 1999). Farmers using this system consider it to be less hazardous than traditional planting in areas with irregular rainfall.

The Maya community of San Jose, Belize [1.5.2q] use a traditional type of slash-and-burn agricultural practice known as the *milpa* (Kass and Somaribba, 1999). In this practice, the soil is left in fallow. Clearing is carried out during the dry season, using an axe and machete to keep in the field Woody species (*Orbignya cohune*) that are of interest to the community. The *Orbignya cohune* is resistant to fire once the lower leaves are removed. Burning occurs just before the first rains, at the end of April (Kass and Somaribba, 1999). Corn is the planted a few days after burning, to make use of the nutritive elements in the ashes.

The Bora, Amerindians of the Amazon in eastern Peru [1.5.2s] and southern Colombia [1.5.2t] survive from *swidden* agriculture, fishing, collecting and hunting (Barton, 1994). *Swidden* agriculture is a traditional subsistence agroforestry system practised by the Amerindians which consists of cutting and burning small plots of forest for crop production, followed by long-term fallowing of the land. Primary and secondary forests are used for their *swidden* plots. Fallows are felled during the period of lowest rainfall and burned after drying. Useful palms and trees, as well as certain valuable timber species, e.g. Spanish cedar (*Cedrela odorata*), are spared during clearing. Coppice regrowth of specific species is recommended. The crop combination of a Bora *swidden* differs extensively with the needs of a family and labour accessibility. Normally, families will have six or more fields in different stages of succession to fallow. Those fields with less diversity tend to be discarded earlier than those in which perennial tree crops have been initiated.

The Kayapo Amerindians of northern Mato Grosso [1.5.2u] and southern Para States [1.5.2v] (Brazil), inhabit areas with maximum species diversity (Barton, 1994). Each zone will supply natural products and attract distinct game species at different times of the year. Their *swidden* plots are set out in the form of concentric rings; the significant crops being sweet potatoes, yams, and plantains. The centre of the *swidden* is dominated by sweet potatoes, a secondary ring begins with maize followed by cassava and sweet potatoes. The outer ring includes yams, cupa (*Cissus gongylodes*), bananas, pineapples, urucu (*Bixa orellana*) and fruit trees. Kayapo *swiddens* vary greatly, and crop combinations rely upon household labour accessibility, hierarchical obligations (communal fields whose surplus is distributed by the chief), personal preferences, ritual obligations (naming and death ceremonies) and internal markets.

The Ka'apor Amerindians occupy a tract of dry land which is not subject to annual floods in the dense forest in northern Maranhao State [1.5.2w], Brazil (Barton, 1994). Once a site has been selected a communal *swidden* is cleared and cultivars from the old site are transported to the new. Ka'apor identified six major vegetational zones (or types of forest or manipulated forest): (a) house gardens; (b) young *swiddens* up to two years from burning; (c) old *swiddens* 2-40 years from initial burn; (d) old fallows 40-100 years from first burning; (e) mature forest and (f) swamp forest.

The Amuesha, which inhabit the tropical rainforests of the Palcazu valley [1.5.2s] of east/ central Peru also practise a form of *swidden* agroforestry modified by their contact with European and the rest of Peru (Barton, 1994). Amuesha agriculture is classified by the diversity of cropping systems, which relate to particular soils, environments and managed fallows. They farm small pockets of fertile soil found on the slopes of the valley. They classify and choose land according to the soil's ability to maintain different forms of vegetation, and fallow times reflect differential fertility status. All their fields are intercropped with a great diversity of minor crops.

Agroforestry management in Asia

South [1.5.3a] and Southeast [1.5.3b] Asia is characterized as the cradle of agroforestry in recognition of its long history of the practice of an array of systems under diverse agro-ecological conditions (Kumar *et al*., 2012). Agroforestry in South Asia [1.5.3a] includes multifunctional home gardens, which encourage food security and diversity; woody perennial-based systems furthering employment avenues and rural industrialisation; fertilizer trees and integrated tree-grass/crop production systems favouring resource conservation; and tree-dominated habitats, which sustain agrobiodiversity and promote climate change mitigation strategies as well as parkland systems; agrisilviculture (the growing of agricultural crops with simultaneously raised and protected forest crops) involving poplar (*Populus deltoides Bartram*) and Eucalyptus spp. (Kumar *et al*. 2012).

Agro-horticulture system and agrisilviculture is widespread in Bangladesh [1.5.3c], India, Nepal [1.5.3d] and Sri Lanka [1.5.3e]. Alley cropping is practised by smallholder farmers in South Asia [1.5.3a]. Moreover, in the coastal tracts of India [1.5.3f], Bangladesh [1.5.3c], Sri Lanka [1.5.3e] and Maldives [1.5.3f] aqua forestry system is dominant. Parkland agroforestry systems are practised in India [1.5.3g] and Pakistan [1.5.3h], while shaded commercial crop production systems are prevalent in the mid and high altitude zones of India[1.5.3g], Bhutan [1.5.3i], Nepal [1.5.3d], and Sri Lanka [1.5.3e]. Parkland agroforestry system is a type of agroforestry system in which large canopy trees are widely spaced in croplands or grasslands. The trees may be either planted or from natural regeneration (Kumar *et al*., 2012).

The *taungya* agroforestry system was developed by the British in Burma [1.5.3j] during the nineteenth century and introduced in South Africa around 1880 (Daff, 2017). *Taungya* agroforestry is a system in which farmers or labour is able to plant crops between timber trees during the early stages of the establishment of forest plantation. It was an improvement of shifting destructive cultivation to the forest reserves in British India.

In Sri Lanka [1.5.3e], the *taungya* agroforestry system is being practised, emphasizing on reforestation of land that is abandoned by non-resident cultivars. In this system, *Tectona grandis* and *Eucalyptus camalduknsis* species are planted and intercropped with agricultural crops (rice, maize, plantain, chilli, and mustard). However, the area under this system in Sri Lanka is significantly decreasing due to lack of interest from farmers.

In the northern regions of Thailand [1.5.3k], *taungya* agro-forestry systems are used by the farmers (Watanabe *et al*., 1988). Tree and crop combinations are used in the *taungya* system, such as tree species (teak (*Tectona grandis*), and fruit trees) and main crops (upland rice (*Oryza sativa*), maize (*Zea mays*) or sorghum (*Sorghum bicolour*)) which are inter-planted in the field. Furthermore, beneath the crops or fruit trees, different kinds of vegetable sub-crops (pumpkin, chilli, and beans) or cash crops (pineapple, mungbean or castor bean) are inter-planted. This then mitigates the high rainfall levels and extended rainy seasons in the south, and longer drought periods in the west, northeast and north regions.

The most common crops inter-planted with trees in the *taungya* system are upland rice in the northern regions, cassava, and kenaf in the northeast, maize, and sorghum in the west and coffee or cashew nuts in the southern region. Therefore tree and crop combinations are changed depending on the season. Maize is thus usually cultivated in the rainy season, from May to August. After the harvesting of maize, sorghum is planted where the maize was grown in reforestation areas in the western regions. In the northern region maize and sorghum are occasionally mix-planted on the same land.

The cumulative temperatures and altering moisture regimes threatens ecosystem services as well as the availability of resources that support the livelihoods of poor and indigenous communities. The application of indigenous knowledge by traditional communities helps societies to manage natural resources in a socially and culturally sound manner which encourages the protection of these resources. Furthermore, indigenous forest and pasture management practices have evolved from cultural norms, traditional values, collective behaviour, and community-based institutions (MOSTE, 2015).

The Madanpokhara community of Nepal [1.5.3l] used local knowledge to collectively manage their forest, they had a set of rules and regulations that govern the removal of forest products, especially fuelwood, fodder, and leaf litter (MOSTE [n.d]). Harvesting was

banned and strictly enforced until the forest cover stabilized. However, according to (Acharya and Baral, 2017) ownership of natural resources particularly land/forests, has always been a symbol of wealth, power, social prestige and security for most of the indigenous people, therefore there is a complex relationship between indigenous people and local communities, their livelihoods and nature. Local people have developed sets of coping mechanisms to deal with water scarcity through centuries of interaction, experimentation, and adaptation.

In China [1.5.3m], agroforestry was practised 1 700 years ago in Shanyang County (Zhaohua *et al*. ed., 1991). To address the great shortage of timber experienced, local farmers were advised to plant a living fence of elm trees. The uniform elm tree belts not only provided enough timber to meet the local requirement but were also beneficial to the growth of crop plants.

The *taungya* system originates from in Southern China [1.5.3n] 300 years ago. In this system, villagers and sometimes forest plantation workers are given the right to cultivate agricultural crops during the early stages of forest plantation establishment. Cultivation is often allowed to continue until trees shade crops due to canopy closure. The system has been reintroduced recently in Southeast Asia [1.5.3b] (Zhaohua *et al*. ed., 1991). The multitudes of agroforestry systems that have evolved in Asia over centuries reflects the accrued wisdom and adaptation strategies of millions of smallholder farmers.

In the flatlands of northern China [1.5.3o], they intercrop agricultural crops with Paulownia elongate; one of the fastest growing trees. Artificial Agroforestry Multiple Ecosystem is also practised in the Lixiahe [1.5.3p] Flatland of China. Farmers also intercrop crops on forest glades; pisciculture in rivers, ponds, and penstock, and grow hydrophilic crops such as fodder and lotus rhizome. All sum up to the agroforestry system where one component symbioses with another (Zhaohua *et al*. ed., 1991). Additionally, Forest-grass System in North Western Loessial Plateau [1.5.3q] and Desert Area is common, due to climate change in the area serious damage in the vegetation resulted in the of fuelwood, forage, and timber, therefore forest grass system plays a key role in supplementing them (Zhaohua *et al*. ed., 1991).

The Hanunoo Mangyan of the Philippines' island of Mindoro [1.5.3r], practice shifting cultivation. They clear the forest for agricultural use, intentionally leaving certain trees. By the end of the rice-growing season, those trees provide a partial canopy of new foliage to prevent excessive exposure to the sun. Similar farming systems have also been common in many other parts of the humid lowland tropics of Asia (Conklin, 1957).

The ifugaos, indigenous people of the Cordillera region [1.5.3s] of the Philippine archipelago have practised agricultural systems that nurture the land and the forest. Those include woodlots and multiple cropping in *swiddens* as economic insurance in case of crop failure in the terraces (Dacawi, 1982). They also practice rice terraces forest – coupled agroforestry system, *kaingin*, and multi-storey System. The rice terraces forest-coupled agroforestry system is known as *"payoh"/"pinugo"/"hayokong"/"hino-ub"* system in the region. The system includes alteration of a sloping area into rice terraces with a close proximity water source. The catchment is an undisturbed forest stand about 5 to 6 hectares wide, managed by either a clan, a family or a group of people using it. In addition, the kaingin called *"uma"/"habal"/"inuman"* is responsible for removing all vegetation including the roots or retaining selected species of trees (Dulay, 2015).

Agroforestry management in Europe

There is a variety of traditional agroforestry systems used throughout Europe [1.5.4a]. Wood pastures are one of the oldest agroforestry system, characterized by the grazing of forests by domestic animals. Cattle, sheep, and goats were transferred to the forest between the end of April and the middle of October (Nerlich *et al*., 2013). Hedgerows and windbreaks are the most important traditional agroforestry systems in the Atlantic region and Central Europe [1.5.4b] (Mosquera-Losada *et al*., 2012 and Nerlich *et al*., 2013). The main role of windbreaks is to prevent wind erosion, as well as provide shade for grazing animals, and maintain a uniform snow cover. Hedgerows were used as boundaries or fences, preventing the mixing of animals (cattle) with neighbouring herds. In Central Europe [1.5.4b], pollarding and pannage were practised. Pollarding is the cutting of branches (when the trees are 10–15 years old at a height of 1.5–3 m above ground) from trees to provide leaf fodder for livestock and produce wood for fuel (*Ibid*). *Pannage* is the grazing of pigs in beech (*Fagus* spp.) and oak (*Quercus* spp.) woodlands for beechnuts and acorn mast (*Ibid*). *Hauberg* is another traditional agroforestry practice that originates from northwestern Germany [1.5.4c]. This is a low forest system, consisting of oak (*Quercus* spp.) and birch (*Betula* spp.) to provide wood and charcoal. After the harvesting of timber, these areas are burnt to fertilize the soil.

In Greece [1.5.4d], agroforestry goes back to the Neolithic period when the community had access to forests by cutting or burning by the man in order to accommodate grazing for domesticated livestock resulting in the creation of silvopastoral systems (Kizos and Plieninger, 2008; Papanastasis *et al*., 2009). Some of the most common agroforestry systems used include: walnut (*Juglans regia* L.), almond (*Prunus dulcis* (Mill.) Webb), mulberry (*Morus alba* L.) and poplars (*Populus nigra* L. subsp. *thevestina* (Dode) Maire), olive (*Olea europaea*), carob (*Ceratonia siliqua* L.) and fig (*Ficus carica* L.) with associated crops such as maize (*Zea mays* L.) and other cereals, tobacco (*Nicotiana tabacum* L.), vines, vegetables and various forage crops such as lucerne (*Medicago sativa* L.) (Mosquera-Losada *et al*., 2012). Special *silvopastoral* habitats are created along corridors or paths along which animals are shepherded. Those consist of oaks that are pruned to either feed animals or build temporary huts for sheltering shepherds and their families.

In Greece [1.5.4d], *Dehesa*-like landscapes are linked with traditional tree management. There are two techniques used for tree management; *"kladonomi"*, known as lopping; and *"koura"*, that is known as *pollarding* (Bunce *et al*., 2004). *Kladonomi* comprizes of the lower branches of the tree being cut for fodder to feed the domestic livestock during winter and/or to build the huts of nomads. *Koura* includes tree branches being cut at a height of at least 1.5-2 m of the trunk making sure that the new sprouts are out of the reach of the animals. *Koura* is used to protect the trees from browsing.

The *baldios* are an ancient tradition in Portugal [1.5.4e], providing rural people with important community forestry benefits (Jeanrenaud, 2001). The *baldios* played an important role in the traditional farming system, providing pasture for goats, sheep and cows, bedding for stable animals, fuel, and construction material and as a source of fertilizer. Today they provide traditional resources and are a source of marketable timber and resin.

In Spain and Portugal silvopastoral systems *Dehesa* (Spain) [1.5.4f] and *montado* (Portugal) [1.5.4e] are being practised. (Joffre *et al*., 1999; Bunce *et al*., 2004; Hernández-Morcillo *et al*., 2014). The system involves two components: (1) a pasture in the understory and (2) a sparse tree, orchard-like. A third component may be included consisting of crops, changing the system to *agro-silvo-pastoral*. In the *dehesa* system, rotational cropping of arable and pasture crops under the trees results in the growth of annual species, promoting high diversity. The most common oak species used in this system are *Quercus ilex* and *Quercus suber* as well as deciduous oaks (*Quercus faginea* Lam. and *Q. pyrenaica* Willd). These species in return provide acorns as a food resource for animals grazing underneath.

In the lowland regions of Transcarpathia [1.5.4g], West Ukraine, the village territory is divided in three levels: (1) the first level (*Mejdele de jos*) is complementary to the terrains near the village consisting of arable fields and meadows; (2) the second level (*Mejdele de mijloc*) which is further away, consisting of hilly areas with small patches of secondary forests and meadows, and; (3) the third level (*Mejdele de sus*) is complementary to the altitudes of 1 000 m and above, the terrains here are mostly used as pasture and forest (Ivașcu and Rakosy, 2017). This type of pastoral system is referred to *double cycling pendulation* system or *pastoralism* in the meadow zone with sheepfold in the mountains (*Ibid*). This system consists of four different phases: (1) springtime (*primavaratul*) – alternate grazing of the sheep on the three levels of the village territory on specific dates; (2) summertime (*văratul*) – conducted in the alpine pastures in summer, the shepherds leave the village territory with the animals (cows, sheep, goats; the horses and oxen) to the alpine pastures to graze the animals; (3) autumn time (*tomnatul*) – the shepherds return back to the village territory and the grazing of the terrains from the upper level (from higher altitudes) to below begin, and; (4) winter time (*iernatul*) –the indoor feeding of the animals, mostly with hay. The sheep are kept under the open sky, but they are enclosed.

In Hungary (East-Central Europe [1.5.4b], Pannonian biogeographic region [1.5.4h]) in Baranya [1.5.4i], Veszprém [1.5.4j], Szabolcs-Szatmár-Bereg [1.5.4k], Borsod-Abaúj-Zemplén [1.5.4l], Békés [1.5.4m], Gyor-Moson-Sopron [1.5.4n], Vas [1.5.4o] and Zala [1.5.4p] counties, wood pastures (oak, hornbeam, beech, acorn- and fruit-bearing trees) are the basis for traditional silvopastoral husbandry (Varga *et al*., 2016,). They consist of a mosaic of grasslands and trees or groves that are utilized mainly for grazing.

Agroforestry management in Oceania

Indigenous folks from the Kingdom of Tonga [1.5.5a] in the central southwest of Pacific Ocean, use various traditional agroforestry systems such as home garden style, slash and burn. Home garden style involves interpolated arrangement, moreover, in this system, various crops and useful plants are cultivated under the tree canopy. They allow farmers to harvest different kinds of staple plants throughout the year (Makino, 2003). Shifting cultivation or "slash-and-burn"), includes a highly diverse range of land use practices. It is practised in a variety of landscapes, from steeply sloped hilly areas to flatlands and low-lying valleys; and in a variety of ecosystems ranging from tropical moist forests to dry tropical forests and savannahs, grasslands, and seasonal floodplains (Thrupp *et al*., 1997).

Customary agroforestry systems operating in Papua New Guinea [1.5.5b] may be classified into four broad categories, defined principally by geographic region, although each has many variants within the region (Kanowski *et al*., 2014). The Highlands agroforestry complex is a combination of sweet potato and casuarina (mainly *Casuarina oligodon*) in a number of complex agronomic and cultural associations across that region. The lowland to mid-montane agroforestry systems is dominated by assemblages of annual and perennial food plants and trees in different combinations. The coastal agroforestry systems are the most diffuse of the four described, largely because coastal populations have historically been relatively small and coastal environments are varied. Lastly, the island's systems are dominated by a range of fruit and nut tree species in association with a number of annual and perennial food crops. These systems are known for being flexible with adaptive management. However, Papua New Guinea landowners have proven very skilful at incorporating new elements or components (e.g., cocoa, coffee) well-suited ecologically, that provide products which contribute either to the subsistence or cash economies, and that can be maintained through intermittent rather than intensive management (Kanowski *et al*., 2014).

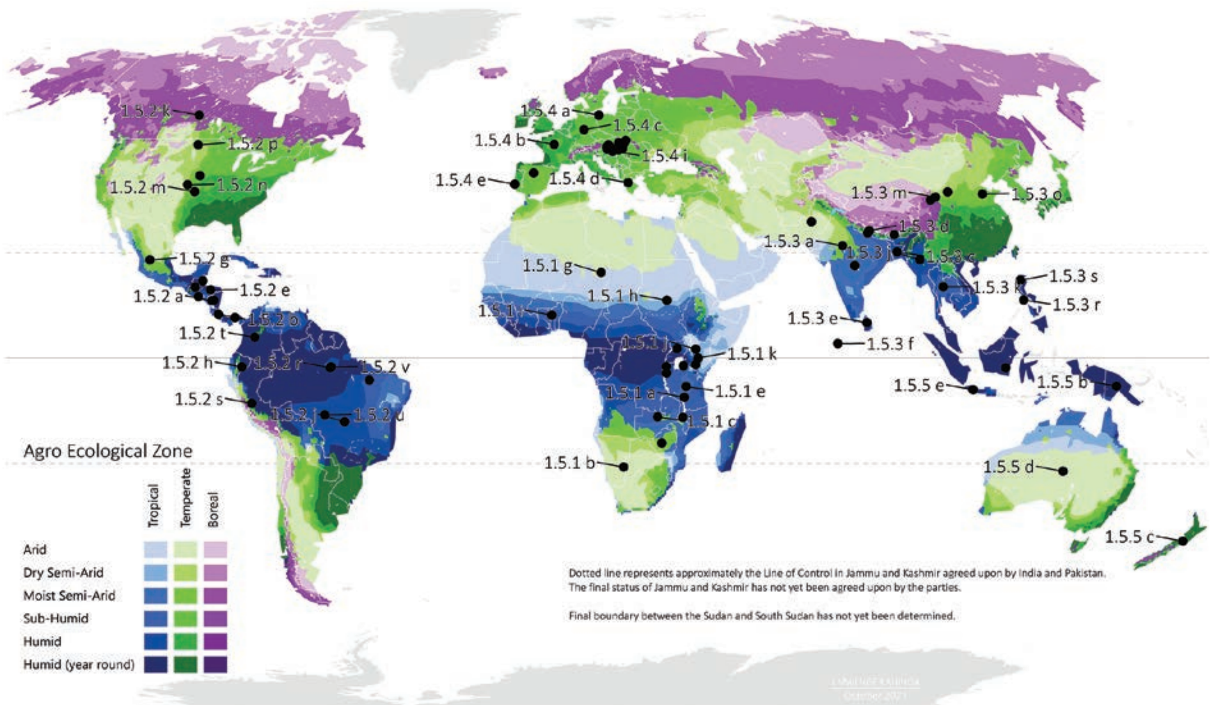
In New Zealand [1.5.5c] and temperate regions of Australia [1.5.5d], agroforestry systems have been

developed over the last 30 years to address the problems of land degradation. Agroforestry systems in Australia include scattered trees in pastures, tree belts and woodlots (Smith, 2010).

Agroforestry systems in Gunung Salak Valley, West Java [1.5.5e], Indonesia include home gardens, fruit tree system, timber tree system, mixed fruit-timber system, and forest understory system (Rahman *et al*., 2016). The home garden system refers to the system where a tree is grown in the home compound consisting of a grouping of plants which includes trees, shrubs, and herbaceous plants. This is a long traditional standing system in Gunung Salak Valley, West Java [1.5.5e], and Indonesia. Timber tree system is rotational based on the planting of a selected timber species, timber trees are harvested at a time when their diameter reaches a size to yield useful timber. They are either directly replaced through natural regeneration, planting, or land use is returned to seasonal crops for a few years before being planted to trees again (Raham *et al*., 2016). Fruit tree system is initiated in agriculture fields, through the planting of fruit trees and understory crops. Normally, this is an irreversible system, as the fruit trees are productive for a long time period. The individual fruit trees are initiated and sustained as integrated components of the system continuously over time with over-mature trees being individually replaced whenever needed. This sustains a high, closed canopy of trees with dense undergrowth and high levels of agro-biodiversity (Rahman *et al*., 2016). Lastly, forest Understory System is used on a restricted scale, primarily only for household consumption. Farmers cultivate in the forest area bordering homesteads and farmland with only a small management input, little disturbance to the forest and no appreciable deforestation. After harvesting the crops are replanted.

In West Java [1.5.5e], three types of agroforestry systems are used, home garden (*pekarangan*), mixed garden (*kebun campuran*) as well as forest gardens (*talun-kebun*). The home garden agroforestry system describes it as a land use form in which several tree species are cultivated together with annual and perennial crops including livestock (Weersum, 1982). A mixed garden is a form of land use dominated by planted perennial crops, mostly trees, under which annual crops are cultivated. The *talun-kebun* is particularly a rotation system between mixed garden and tree plantation. The *dudukuhana* system, also prevalent in the West Java region [1.5.5e] (Manurung, *et al*., 2006) are traditional farming systems divided into timber system, mixed fruit-timber-banana-annual crops system, mixed fruit-timber system, and fallow system. All types of *dudukuhan* are managed on an extractive basis, with few inputs.

Figure 6. Geographical locations of narrated agroforestry management case studies



Source: World Bank, 2021 & Plevin *et al.*, 2014, modified to comply with UN Geospatial. 2021. *Map of the World*. Washington, DC, UN.

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TOPIC 1.6. INTEGRATED WETLANDS AND FISHERIES MANAGEMENT

Integrated wetlands and fisheries management in Africa

A case study of farmers' strategies for adjusting to climate vulnerability in the low valley of Ouémé [1.6.1a] reflected that local people have established an exceptional ability to adjust to climate threats, or in some cases have turned threats into opportunities. From fishing practices to agricultural techniques through agro-fishing practices, people of the low valley of Ouémé were capable of taking advantage of their natural vulnerability through adaptation strategies mostly based on local knowledge (Yaro, 2010). The Ouémé valley [1.6.1a] people of Benin take advantage of succession and regularity of flooding and recession periods in floodplains. Indeed, the finger ponds dug mostly in flood-plains aid as refuges for wild fish migrating during the flooding. At low-water levels, these indigenous species of fish are tamed into the holes and become easy prey to farmers. More so, in the coastal zone, according to the men, most farmers who previously were into cultivation of cassava and maize have now changed to onion cultivation, since onions are easier to store and sell later for more money (Yaro, 2010).

Communities of Illubabor [1.6.1b] and Western Wellega [1.6.1c] zones in Oromia Region, Ethiopia, play a key role in coordinating wetland management and sustaining the benefits from wetlands (Dixon, 2008). Wetlands provide a variety of hydrological and ecological benefits, such as the recharge and discharge of groundwater, flood control and retention of sediment, as well as maintaining the biodiversity of specially adapted flora and fauna (Dixon, 2001). Farmers in Ethiopia [1.6.1d] use these wetlands as reservoirs of moisture during dry periods, as well as to cultivate maize much earlier in the season than on the uplands. Therefore, maize crops are harvested before maturation (during its 'green' phase). Wetland plants are also used by farmers as indicators of changes in soil fertility or hydrological conditions (Dixon, 2001). The *kemete* plant (*Leersia hexandra*) is related to the degradation of wetlands. If these plants start occupying the wetland, farmers become aware that they need to actively rehabilitate the normal flooding regime in order to increase wetland fertility. Comparably the *inchinne* plant (*Triumfetta pilosa*) is used as an indicator of increasing fertility, therefore its development in a wetland is considered as the end of a fallow period by farmers. Indigenous knowledge of these plant indicators represents a critical way in

which the local community can evaluate the state of their wetland and consider a suitable measure to ensure wetland use is sustained.

In Rwanda [1.6.1e], wetlands are used because of their large water reserves, lower erosion risks, and natural fertility. There are four types of vegetation on Rwanda's wetlands (Mbabazi, 2011). First, wetlands dominated by the *papyraie*. They are characterized by abundant water and the vegetation of *Cyperus Papyrus* (Paper reed) thus containing water throughout the year. Second, wetlands dominated by *Cyperus Latifolius* (Njekenjeke). They have low water content below the soil surface, making them suitable for cultivation during the dry season. Third, wetlands dominated by shrub-like vegetation. This vegetation rarely retains any water, however, water is available during rainy seasons. Fourth, wetlands dominated by grass. They are used during the dry season.

The Kilombero Valley in Kilombero District [1.6.1f], Morogoro Region, Tanzania [1.6.1g] contains the largest freshwater wetland at low altitude in East Africa (Kangalawe and Liwenga, 2005). Most farmers of the Kilombero Valley use wetlands to grow rice, maize, bananas, vegetables, and cassava, either during the rainy season or in the dry season. In the late 1900s, most of the livestock keepers in Signali village began herding their livestock in the wetlands as a result of the availability of good pastures and water found in the wetlands.

Integrated wetlands and fisheries management in America

In the Altiplano [1.6.2a] of Peru water bofedales (areas of wetland vegetation that may have underlying peat layers) is a key resource for traditional land management at high altitude (Fonkén, 2014). Because they retain water in the upper basins of the Cordillera, they are important sources of water and forage for domesticated livestock during the dry season, as well as biodiversity hotspots. The knowledge of their and management is passed down through generations (Saylor *et al*., 2017). Bofedales are increasingly threatened by overgrazing, peat extraction, mining and development of infrastructure.

Integrated wetlands and fisheries management in Asia

Prepared bait (*Char*) and hooks (*Kanta*) for capturing fishes like Indian Major Carps (high market value fish) (*Ibid*). This fishing technique is cost-effective in providing daily food and assists the livelihood of poor fishers. This fishing method is utilized throughout the year in stationary and low tidal areas of the river; requiring 2-4 hours for each operation.

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Lake Kolleru is the largest freshwater lake in India [1.6.3a], situated between two major rivers, the Godavari and the Krishna, in Andhra Pradesh. The outlet of the lake to the Bay of Bengal, plays an important role in the conservation of the wetland's hydrological regime, functioning as a natural flood-balancing reservoir for both the rivers. The lake is a source of water for domestic use and irrigation and also traditionally maintains a significant fishery. The lake is extremely productive further providing habitat and good breeding and feeding ground for species of migratory and resident birds (Raju *et al*., 2016). A large proportion of the people living in the area are dependent on capture fishery practices. The fishing craft and gears adopted by fishermen community of Lake Kolleru were simple, mostly old fashioned and indigenous. Indigenous traditional fishing knowledge and methods of the fishing community of Lake Kolleru is diverse, and some of them are unique. The use of diverse craft and gear, as well as fishing methods, are determined by the physiography of the lake area, the financial status of the fishermen and season.

Fishing crafts (*Dhoni/ Thati Dhoni*) are made from basal parts of the Palmyra tree trunk, and plank-built boats are made of wooden planks. The smaller boats (non-mechanized) are used to transport harvested fish and also passengers from village to village within the lake. Bigger boats (mechanized) are longer and used to transport fish to landing centres. Thermacol raft is an interim fishing craft made of used thermacol boxes and slices (for fish preservation and transport). The raft is often managed by children of 10 – 15 years of age for setting and collection of traps, transport of catch and fish trap near the lake shore.

One of the oldest and widely used fishing methods is the fishing Gear (*Galamu*/Hook and line), this method is not commercially used and fish caught is consumed by the fishermen and their families. During October to February *Dadikattu* (fish screens) is practised when the water level is high in the lake. Bamboo screens are constructed across the lake and traps are set in single rows on both sides of the screen and kept in position by packing aquatic plants and mud at their bases.

Box trap, locally called *"Mavu"* is a passive fishing device in which baits are kept inside the trap to lure the fish. In Lake Kolleru, rectangular shaped basket trap locally called *"Pandirimavu"* is commonly used. *Moora Bethe Mavu* is the largest basket trap used; *Moora mavu* is used to catch medium-sized fish, and *Ingilayi Mavu* is used to catch small and medium-sized fish. *Gampagari* (Tubular Basket Trap) is a funnel-like (*Gampa*) trap used to catch small and medium-size fish from October to January. *Sanchi Vala* (Bag Net) is a bag like net used in shallow water regions of the lake. *Ettudu Vala* (Hand Lift Net) is a small, mobile hand operated net which is also used in the shallow regions of the lake to catch small fish. *Visuru Vala* (Cast Net) is used in shallow waters of the lake where depth is about 2-3m. Cast nets can be used single-handedly whereby fishermen throw the net over the water either from a boat or from the banks of the lake.

Odhe (Cover Basket) is a falling gear operated by a single fisherman in shallow waters during dry seasons. The gear is placed against the mud to prohibit the escapement of fish and are caught by hand picking. *Lagudu Vala/Pedda Vala* or *Pattu Vala* (Drag Net) is an effective gear for catching wild fish populations and used for huge water bodies such as Lake Kolleru. *Moppa Vala* (Gill Net) is a rectangular gear that is erected into a water column vertically perpendicular to the movement of fish.

Indigenous fishing methods used for fishing in Lake Kolleru are as follows, grouping (hand picking), *Doddi* fishing (dewatering), *kampagudu* [Fish Aggregate Device (FAD)] and *Gaya*. Grouping is the oldest of various fishing methods and is practised in summer. Fish is caught from the shallow waters of the lake by hand without any device. *Doddi* fishing is practised in the dry season, in deeper areas of the lake where fish tend to congregate. *Kampagudu* is a fish aggregating device used to assist in fish harvesting by luring and aggregating fish. *Kampagudu* is customarily practised at points where the water flow is minimal. This method reduces scouting time for fish and also improves fishing efficiency as a result of increased time available for fishing. Lastly, *Gaya* is practised in summer when the water levels are reduced.

Many communities in the Asia-Pacific [1.6.3b] region traditionally implemented conservation rules to ensure sustained yields (Kalanda-Sabola *et al*., 2007). Some of the practices included live storage or freeing surplus fish during spawning migrations, reserving certain areas for fishing during bad weather, placing taboos on fishing areas, and setting up of closed seasons during spawning. Fishermen used traditional gear to catch fish, such as fish traps (mono), spears (momba), hoe handles, sticks, and locally made fish hooks (mbedza) and gill nets (ukonde).

In the late 19th century, Japan [1.6.3c] returned to practising traditional community-based management for all inshore coastal fisheries. Cooperatives decided on the operational rules (gear, season, fishing areas, *etc*.) based on the experience of the fishers.

Integrated wetlands and fisheries management in Europe

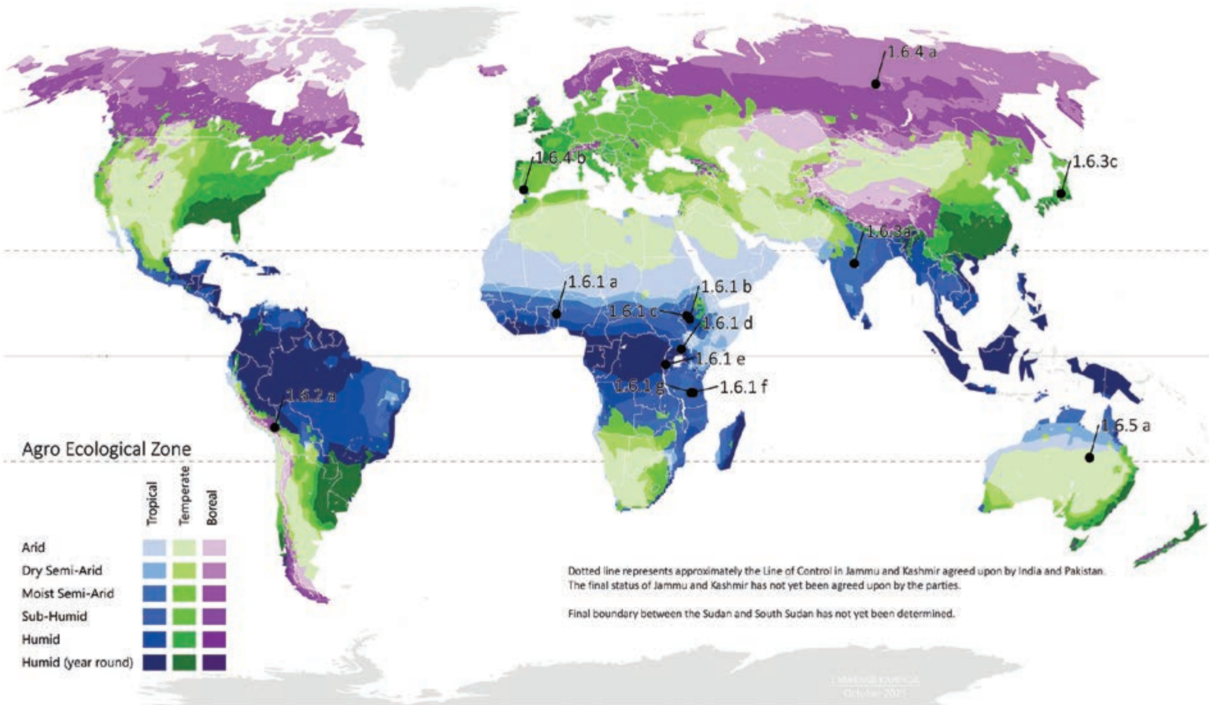
In Russia [1.6.4a], the seasonal changes in flora are used to establish when it is time to begin hunting and other activities. Changes in larch (Larix lyallii) foliage is used by the Udege and Oroch tribe to time their fur hunting season. The blooming of wild rose indicates the start of salmon spawning, while a rich harvest of Siberian pine nuts indicates good hunting prospects for fur and hoofs (Bocharnikov, 2011). The Udege people from the Bikin River basin adapt their fishing and hunting activities on an understanding of local ecological conditions. When salmon are abundant in rivers, they increase their fishing activities and then drying and storing surplus catches for the winter months (*Ibid*).

In Doñana [1.6.4b], southwestern Spain, hunting and fishing areas restricted during the reproductive seasons of key species (Gómez-Baggethun *et al*., 2012).

Integrated wetlands and fisheries management in Oceania

Indigenous ecological knowledge is deeply rooted in the customary land and sea tenure institutions in Oceania [1.6.5a]. Consequently, governance and management systems are based on cultural and historical practices that have evolved over the years, to regulate the use of, access to and transfer of local resources (Aswani *et al*., 2012). For instance, forms of marine territoriality, such as common property rights-based systems, are arranged and approved by stakeholders (Cohen and Foale, 2011). The tenure right identifies particular users as having exclusive rights over resources and it has the ability to exclude non-members from accessing and using them. Rights of inclusiveness are distinguished via a number of socio-cultural rules based on birth (primary rights), marriage and residence (secondary rights), and the direct transfer of rights by traditional authorities (Aswani *et al*., 2012).

Figure 7. Geographical locations of narrated integrated wetlands and fisheries case studies



Source: World Bank, 2021 & Plevin *et al.*, 2014, modified to comply with UN Geospatial. 2021. *Map of the World*. Washington, DC, UN.

THEME 2: SEMANTICS

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Objective: ***to explore the appropriate terminology for the technologies and practices under discussion.***

This document report endeavours to utilize the benefits of identification, collation, and inclusion of different knowledge systems as part of climate change adaptation. It does, however, conflate terms such as indigenous knowledge, community knowledge, local knowledge, and community knowledge. While those terms are related, they have significant differences, also which is used interchangeably causes confusion and exclusion. In addition, in many instances, the term indigenous is also used as a catch-all to include other types of pieces of knowledge. Again this is problematic as indigenous knowledge refers to a specific kind of knowledge system associated with indigenous peoples only. Since these terms provide essential guidance to the discussion at hand in the document their use and definition needs revision. In the sections below, we briefly introduced most of those terms.

TOPIC 2.1 DISTINGUISHING BETWEEN LOCAL AND INDIGENOUS KNOWLEDGE

Local knowledge

Naess (2013) defines local knowledge as follows: "local knowledge can be defined as the unique knowledge developed over an extended period of time and held by a given society in a specific location". Sillitoe (1998:204) also presents a definition of 'local knowledge', but specifically linked to the development context. For him local knowledge "may relate to any knowledge held collectively by a population, informing the interpretation of the world".

In both of these definitions, local knowledge is presented as the knowledge that is held by a particular group of people over time in order to understand the world they live in. Further along in their arguments both of these authors also suggest that local knowledge is shaped by social and cultural traditions and that knowledge and skills, as well as ways of managing environments, are linked to worldviews embedded within the social and cultural context in which the knowledge is held.

It is important to note that local knowledge is not exclusively linked to indigenous peoples, however, it may include them. Berkes *et al*. (2000) in their discussion on knowledge systems also makes a clear distinction between local communities and indigenous communities. As such, if one were to use the two terms interchangeably one may lose any examples that do not emanate directly from indigenous communities.

Indigenous knowledge

Mascarenhas (2004:5) defines indigenous knowledge as "the total sum of the knowledge and skills which people in a particular geographical area possess, and which enables them to get the most out of their natural environment". An important point emphasized by Mascarenhas here is that the knowledge and skills are passed on down from previous generations and are then adapted and added by the new generation as a way to equip them with survival strategies in a constant adjustment to changing circumstances and environmental conditions.

The term indigenous knowledge is however extremely value laden. For example, Heyd (1995) argues that for most authors the term 'indigenous' is problematic as the term infers that it may only be knowledge held by indigenous people where the term indigenous stands for "aboriginal, native or autochthonous, though; that is, it is used to make reference to the knowledge of the people who comprize the descendants of the original inhabitants of a land" (Heyd, 1995:63). In this sense, by using the term indigenous people or knowledge one would exclude all other kinds of knowledge that do not adhere to these restrictions. As such one can see how indigenous knowledge can be understood as local knowledge, however, the converse cannot be true.

The terms of indigenous knowledge and traditional knowledge are often used interchangeably without much confusion, however, the term "traditional" is also considered value-laden. In this case, authors (Sillitoe, 1998; Berkes, 1993; Berkes *et al*., 2000; Naess, 2013) warn that the use of the term might evoke notions of hierarchy related to ideas about who or what might be civilized thus juxtaposing that which is considered traditional with that which is considered modern, equating modern with civilized. We would, therefore, suggest that using the term indigenous as a catch-all for local, traditional and indigenous knowledge may cause unnecessary confusion as well as negative labelling.

"Indigenous knowledge" is an expression that still has evolving conceptual.

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TOPIC 2.2 CLARIFYING THE USE OF TEK AS ALTERNATIVE

As an alternative to the interchangeable use of local and indigenous in relation to knowledge in the document, we propose the use of the term 'traditional ecological knowledge' (TEK). TEK is a well-established term within the literature on knowledge systems utilized by people in relation to their environment. Berkes (1993) presents a unified definition of TEK based on a number of definitions from diverse authors:

> *"TEK is a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment. Further, TEK is an attribute of societies with historical continuity in resource use practices; by and large, these are non-industrial or less technologically advanced societies, many of them indigenous or tribal".*

Another definition of TEK that builds on the Berkes (1993) definition comes from Gómez-Baggethun *et al* (2013: 71). They argue that TEK "consists of the body of knowledge, beliefs, traditions, practices, institutions, and worldviews developed and sustained by the indigenous, peasant, and local communities in interaction with their biophysical environment (Gómez-Baggethun *et al*., 2013: 71).

Using TEK as defining framework one avoids eliminating knowledge that is not explicitly labelled 'indigenous', in addition, it will alleviate the confusion between exactly what is 'local' knowledge. In addition, for the purposes of this document the knowledge systems and practices identified should be explicitly linked to people and their relationship, management, and understanding of their natural environment. The TEK definition provides this. TEK also retains important characteristics such as knowledge that is handed over from one generation to the next; historical continuity in relation to the keepers and knowers of knowledge; knowledge linked to a distinct group of people; and includes other forms of knowledge such as local and indigenous where they are explicitly linked to the environment. Lastly, studies on TEK have shown its contribution to improving livelihoods, sustaining biodiversity and ecosystem services; and building resilience in social-ecological systems (Berkes, 1993; Berkes *et al*., 2000; Folke, 2004; Gómez-Baggethun *et al*., 2013).

In order to be able to identify relevant TEK examples, we suggest the use as the following characteristics

(adapted from Berkes, 1993) presented below as identifiers. By using these characteristics as identifiers one also solves the methodological predicament of rationalising the choice of known examples used in the document. The suggested characteristics are:

- TEK is mainly qualitative especially in its translation into data (as opposed to quantitative);
- TEK has an intuitive component (as opposed to being purely rational). In other words, the question is not whether something can be proven, rather what effect does it have on behaviour and practices;
- TEK is holistic (making sense as a whole) as opposed to reductionist;
- TEK has embedded within its morals and does not operate value-free;
- TEK is often linked to spiritual aspects of life and being;
- TEK is based on empirical observations and accumulation of facts by trial-and-error;
- TEK is based on data generated by resource users themselves and not by a team of researchers;
- TEK is based on diachronic data, in other words, long time-series on information on one locality and not synchronic data (short time-series over a large area).

THEME 3: GOVERNANCE

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Objective: ***to identify factors influencing an enabling environment for the adoption of the practices and make recommendations***

TOPIC 3.1 LAND TENURE SYSTEMS

Land tenure represents systems of rules and regulations that oversee land acquisitions by various people in that community (Yelsang, 2013). Land tenure has also been described as a codification of the procedures which function by specifying what different classes of persons may or may not do, with reference to the occupancy, use, abuse or disposition of land. However, these procedures describe the privileges and obligations, the rights and duties of persons in relation to each other, with reference to land (Famoriyo, 1979; Pierre, 1997; Cousins & Claassens, 2009; Johnson, 1972).

Traditional or ancestral land that indigenous and traditional peoples inhabit represents the fundament of their cultures. It is estimated that traditional and indigenous peoples, who only constitute to about five per cent of the world's total population, occupy about 20 per cent of the world's land surface (Oviedo *et al*., 2000). These peoples have managed and shaped their surroundings over centuries, adapting their livelihoods to very specific local natural, physical and climatic conditions. Many of the ancestral territories that indigenous and traditional peoples dwell in comprize sacred natural sites represented in the form of mountains, rivers, lakes, caves, single trees or forest groves, coastal waters, and entire islands. Traditional and indigenous peoples are tightly connected to their land, not only through their livelihoods but also through spiritual bonds (Below *et al*., 2010).

However, in many cases, land tenure and access rights of indigenous communities are not legally recognized (*ibid*). As a consequence, their land and resources are often exploited and encroached by outsiders. This insecure situation further "acuminates the already challenging situation many of these peoples live in and may result in severe implications to their vulnerability and capacity to adapt." (Below *et al*., 2010). For instance, in times of acute climatic crises,

people often shift their agricultural activities to more favourable areas. The Makushi of Guyana, for example, move their savannah homes to forest areas in times of droughts (Salick and Byg, 2007). If this traditional way of adaptation to environmental variability is restricted or denied these people might not be able to cope with environmental stresses and be at acute risk. Consequently, it is crucial to protect land tenure and access rights of traditional and indigenous peoples and to reward them for the goods and services their lands provide (Below *et al*., 2010).

Similarly, women and young people have not been lucky enough to inherit landed property or do not have financial resources to invest in landed property ultimately lose out. Assets alone are not enough, but the social and economic conditions that allow people to use these assets to earn a decent livelihood are. There is a reduction in interest in agriculture among youths, which has led to migration becoming a cross-cutting issue affecting all agro-ecological zones, with significant consequences for the receiving areas in urban and agricultural frontier zones (Yaro, 2010). Many more women are poorer than men in all regions, which is a reflection of traditional patriarchal norms translated into current access patterns to resources and privileges enjoyed by the different sexes. Traditional inheritance systems give precedence to men over women (Levin *et al*., 1999; Quisumbing *et al*., 2001; Awumbila and Ardayfio-Schandorf, 2008).

Land tenure in Africa

Colonial settlers imposed a statutory system governed by laws and regulations and supported by written evidence, such as a title deed or lease certificate, and administered by the government (Quan, 1997 and Cotula *et al*., 2004). It is often built on freehold or leasehold entitlements and offers exclusive rights to the owner, which guarantee the security of tenure. Land rights in freehold include the ability to sell the land, rent it to others and to use it as collateral for a mortgage (Kasang *et al*., 1996; UNECA, 2003; Chagutah, 2013; Kasimbazi, 2017). Colonial settlers introduced this system for the legal guarantee of private ownership of land, without which they were reluctant to invest. The property rights model of the neo-classical theories was the major influence towards land privatisation. Neo-classical theory argued that traditional African land tenure system induces inefficient allocation of resources because property rights are not clearly defined, costs and rewards are not internalized, and contracts are not legal or enforceable (Barrows& Roth, 1990). Economists who are in favour of privatization also argued that land titling would increase economic efficiency, given that legal title to land allows its owner to use it as collateral, thus increasing access to scarce finance capital for investment. These arguments have led various African governments and international agencies to push for the privatisation of land even

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after independence (Griffin *et al*., 2002). However, a number of studies conducted to evaluate the performance of these reform measures indicate that they have largely failed to benefit the concerned rural people. In some countries, the policy of privatisation has caused adverse effects in practice (Cotula *et al*., 2004; Elahi, 2013; Lund, 2000). In Southern Africa, this tenure system has created a situation whereby the best land is monopolized by commercial sector while the majority of the poor are clustered in unproductive communal lands. Although there is a growing appreciation of the suitability of communal systems in the African context. Extinguishing communal property rights and replacing them with private property rights often failed to bring about the anticipated efficiency gains, yet it did create a tendency for inequality in the distribution of productive wealth to increase. Typical examples of countries where this occurred are Kenya, Namibia, South Africa and Zimbabwe and, in North Africa, in Algeria and Morocco. In Ethiopia under the empire, land ownership was concentrated, but the poor were not displaced to marginal land; instead, they served the landlords as tenants (Griffin *et al*., 2002).

The legacy of the oppressive and racially based policies of colonial governments is still reflected in dualistic land tenure systems and inequitable land distribution patterns. This problem manifests itself in different forms across Africa. Land tenure in most African countries is commonly described as either customary/traditional or state/statutory held under leasehold or freehold. Customary/ traditional land tenure dates back in the antique times before the imposed colonial system when land was owned and controlled by the community with severe restrictions of individual land rights (Johnson, 1972). Prior, colonisation land in the African continent was perceived as a resource to be used; not as a commodity to be leased and sold. Thus, communal land/traditional tenure offered communities free access to common property resources (Adams *et al*., 1999). In communal land ownership uncultivated forest land, woodland rangeland are communally owned and controlled by traditional authorities; while cultivated land is allocated to individual households and its ownership rights are held traditionally by the extended family. The uncultivated portion of communally owned land is considered as common property, which is defined as the joint ownership and use of the property by a group of people, e.g., for hunting and extraction of trees and minor forest products. It is an open-access property with no restrictions to the community members (Ault and Rutman 1979; Bruce, 1982; Bruce and Migot-Adholla, 1993).

Land tenure in America

The distribution of land in Latin America has long been the most unequal in the world. Large landowners known as *latifundistas* owned roughly 80 per cent of the land and accounted only 5 per cent of total landowners; while *minifundistas* accounted for about 80 per cent of all landowners, but with only 5 per cent of the land. Approximately one-third of the agricultural labour force was landless. The landless and most *minifundistas* worked on *latifundia* (large landed estate or ranch) as permanent or seasonal workers, as tied labourers under service tenancies or as sharecroppers (Griffin *et al*., 2002). Latin America undertook reforms which included the transformation of *hacienda* estates that took more indigenous land thus resulted in the dualistic land tenure system. This dualistic tenure system was distinguished by quite a few large commercial estates known as *latifundios* (>500 ha) and numerous small properties known as *minifundios* (<5 ha). These were mainly subsistence-oriented smallholdings operated by indigenous and peasant households (Chonchol, 2003 and Griffiths, 2004). The main aim of the agrarian revolution was to reduce poverty and support peasant farmers. Mexico, Bolivia, and Cuba also expropriated nearly half of the land to the rural population (Guatemala, 1954). The land reform policies in Latin America failed to engage indigenous people and the rural poor. As a result, commercial landowners managed to preserve more fertile land whereas indigenous people received plots on marginal lands (Itturalde, 2001; Griffiths, 2017).

Smallholder farmers are also marginalized in terms of financial and technical support. Governments continued to neglect investment in human capital in the countryside; and public investment in rural transport, power, and communications continued to be meagre, particularly in areas where small farms predominate. As a result, the benefits of land reform are often unsatisfactory. Land reform helped to transform many *latifundia* into capitalist, commercial farms (Griffin *et al*., 2002; de Janvry 1981; de Janvry and Sadoulet 1989).

In North America, individuals and not the Crown were the ultimate owners of land, and for the most part, it was allocated in small plots. Individual land ownership, speculation in land, and participation in capital markets based on land as collaterals were widespread in North America. Property rights are governed by English laws, customs, and legal institutions, these were modified through the statutory enactments of local representative assemblies and rulings of common law courts. Consequently, property rights in land became a liquid source of wealth, to be bought and sold and used to obtain credit. The informal flow of land in the market facilitated extensive property ownership, undermining privileged inheritance and inalienability. Dynamic, open land markets became an essential ingredient for the credit system and its ability to support the growth of a middle class as well as to spur investment and innovation throughout the economy (Libecap and Lueck, 2011).

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Land tenure in Asia

Historically, Asian land was communally owned by tribes, clans, and extended families, and was administered by village chiefs. Shifting cultivation was the main source of livelihood. Individuals required consent from the village head to cultivate the land. Once the land was cultivated, it could be passed on to their children. Customary tenure and traditional institutions were mainly founded by local customs and traditions. Institutions and rules relating to customary tenure directed access, use, use change and transfer of shifting cultivation of land (Anderson, 2011). In addition, these communities believed that land is closely tied to their beliefs, customs, and traditions. Customary land tenure system prevailed in Southeast Asia and parts of South Asia; it continues to be practised today among many communities of indigenous peoples who have resisted colonial rule and foreign cultures. Although, in some parts of Asia for instance in China feudalism was widely practised with tribute paid to the emperor through a hierarchy of vassals, tribes, and clans (Quizon, 2013). Colonial settlers forcefully took native land and introduced individual land ownership. Nevertheless after independence about 22 Asian countries implemented land reform programmes between the mid-1940s and the 1980s. These land reforms played a key role in state building, which was characterized by inward-looking economic policies. The type of land reform introduced followed two ideological perspective, socialism and capitalism. The capitalist view was a key approach to strengthen private property rights mainly in the form of individual family farms. While, the socialist view, on the other hand, was to liquidate private property in favour of socialist development driven by the state, taking the form of cooperative and collective farms (Quizon, 2013). China, for instance, follows a system of socialist public ownership. Rural land is collectively owned by the communities except for those portions which belong to the State as prohibited by law; house sites and privately farmed plots of cropland and private hilly land are also owned by collectives (Rosato-Stevens, 2008).

In pre Hispanic Philippines, indigenous land-tenure system was characterized by communal ownership of land with a feudal system in it. Individual families had usufruct rights to a parcel of land. In return families were required to perform various public services, often consisting of assisting the *datu* in the tending of his fields and home (Riedinger, 1995). Since 1987 the Philippines constitution recognizes the land rights of indigenous cultural communities. Similarly, Indonesia's Basic Agrarian Law of 1960 stipulates that the national land law shall be based on '*Adat*' (customary) law and shall incorporate customary concepts, principles, systems, and institutions (Kasimbazi, 2017).

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Land tenure in Europe

The most significant land ownership in Europe was the Feudal system. Landlords owned large estates farmed by labourers and tenant farmers, known as serfs, who also lived on the estates. Serfs could not own land and did not receive a cash remuneration for their labour, but were provided with a small portion of the crop as payment often, some of the crop payment they received had to be paid back to the landlord for rent. The serfs were obliged to work the land and could not move from under their landlord (Millward, 1982). However, the European transition from socialism to a market-based economy was the privatisation of agricultural land (Giovarelli and Bledsoe, 2001). The land of farmers' co-operatives and state farms was returned to the legal owners of the land prior to the socialist government with the aim of developing a viable private agrarian sector. Several scholars argued that the privatisation of farmland leads to the division large farms which were economically efficient units to small privately owned plots with much reduced economic viability, consequently, a number of rural areas experience complex issues (Swinnen *et al*., 1997; Dijk, 2006). Political regimes, on the other hand, advised that secure and unrestricted private property rights of land and other productive assets are essential to ensure the most efficient form of agricultural production (Lerman *et al*., 1995). A number of positive aspect such as reduced fragmentation in the agricultural sector have been experienced in the Western European. As a result, many rural areas encountered substantial problems caused by the inconvenient structure of farms and highly fragmented ownership of arable land (Dijk, 2003). Nevertheless, in these Western countries, there are still many restrictions on the selling and buying of land, there are limitations on the extent of land which can be owned, and there are criteria for selecting the persons who are eligible to own land for the purpose of farming (Granberg *et al*., 2001).

Land tenure in Oceania

Traditional land tenure is known to provide stability in the Pacific Islands. In the Pacific region, there are three different types of land tenure systems, customary, public and freehold system. More than 80 per cent of the land is governed under customary tenure, while public and freehold land represents only a small proportion of a country's land area, it is often located in the most productive and accessible places, and is usually supplied with the infrastructure for economic and social development. Aspects of customary land tenure are similar to other regions of the world that include inheritance, allocation of usage rights, dispute settlement. Public land is owned by the state whereas freehold land is owned and controlled by individuals or corporate bodies (Ye, 2009). In Australia, land holdings are based on the doctrine of tenure, the feudal system of land management inherited from English common law. An estate in fee simple, commonly referred to as freehold land ownership is by virtue of a grant by the Crown. All land which is not the subject of such a grant remains as Crown land and may be subject to a Crown or state lease or some other tenure type. Under leasehold land tenure, ownership of land is based on the notion of rentals for long periods. Land belonging to one entity either the State or an individual is by contractual agreement, leased to another entity. While a Crown land tenure is an agreement between an individual or company and the provincial or federal government which provides the individual or company with an interest in the land. Tenures are granted for specific purposes and periods of time (Sutton, 1996).

THEME 4: YOUTH ATTITUDE, TABOOS, ALTERNATIVE LIVELIHOOD AND OTHER PRACTICES

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Objective: *to identify other factors affecting the sustainability of the technologies and practices.*

TOPIC 4.1. THE YOUTH'S ATTITUDE TOWARDS TECHNOLOGIES AND PRACTICES

There are many causes or reasons as to why Indigenous knowledge/Traditional Ecological Knowledge are marginalized (Ocholla, 2007):

- the knowledge is not codified nor systematically recorded and therefore difficult to transfer or share;
- the knowledge lives solely in the memory of the beholder and is mostly oral, meaning that unless transferred, it dies with the beholder;
- the knowledge is embedded in the culture/traditions/ideology/language and religion of a particular community and is therefore not universal and therefore difficult to globalize;
- the knowledge is mostly rural, commonly practised among poor communities and is therefore not suitable in multicultural, urban and economically well-provided communities;
- the knowledge is perceived to be primitive and old-fashioned, and therefore has no value;
- families and communities are becoming increasingly disintegrated and globalized, and;
- Some issues raised do not have any scientific basis.

Youth's attitude towards technologies and practices in Africa

In Tanzania, Ngono River basin, Muleba and Missenyi districts, traditional healers were highly respected by the community, however, this is no longer the case. Similarly, due to the lack of respect of the traditional culture and taboos that exists in the communities, most of the elders who are the custodians of this knowledge are less willing to share this knowledge with the younger generation. It was found that the current generation is not interested in indigenous knowledge due to a number of factors, including modernization (Theodory, 2016).

Currently, the indigenous knowledge is in danger of being lost if it is not well documented as community elders, who are the main custodians of this knowledge, are swiftly decreasing within the community. Of critical concern is the growing perception among the younger generation of indigenous knowledge as outdated and inefficient, with little potential for incorporation into current development policies (*ibid*).

Fabiyi and Oloukoi (2013), go further to argue that, even though the realities and the confirmed efficiency of indigenous knowledge, some issues have yet to be addressed. For example, "scientific efficiency and the transferability of indigenous knowledge from generation to generation." Since these knowledge systems have not been documented, they can easily be forgotten. In the past, indigenous knowledge was transferred to younger generations through folk tales, communal festivals and age grade initiations. However, all these oral traditions are considered to be local and outdated by the younger generations today, which means that this knowledge will never be learned by the youth in the communities (*ibid*).

Turkana pastoralists in northern Kenya, particularly the women, have developed a traditional knowledge of the local flora and their uses. For example, trees are important because they provide fuelwood, building timber and household utensils. Certain important trees are protected by custom (Barrow, 1996). In the long dry season, the women cut small branches to feed livestock and collect pods and fruits of certain trees (for example, Acacia tortilis) for fodder and food. The Turkana communities also use tree products for medicines, some of which have important clinical properties (Barrow and Mlenge, 2003). More so, to manage their wet, dry and drought time grazing areas, the Turkana tribe have a number of institutions for natural resource management, which, with their accompanying rules and regulations, are under the control of the Turkana elders, and, in some cases the women (*ibid*).

Traditional communities have a long history of responding to climate change variability. Indigenous and newly introduced adaptation practices have helped communities adjust with both current climate variability and future climate change.

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TOPIC 4.2. TABOO, CULTURAL, RELIGIOUS AND SPIRITUAL BELIEFS

Indigenous knowledge of environmental change has been created by encounters of community inhabitants, and it is further indissolubly connected to culture-space, place, meaning, and identity (Berkes, 2009). Prior to the existence of central governments, local communities were governing their resources through customary regulations. Taboo, cultural, religious and spiritual beliefs continue to govern natural resources in many communities around the world. Through roots in cultural and religious spheres, traditional practices have helped communities benefit from the traditional systems and minimized climate change impact.

African taboos, cultural, religious and spiritual beliefs

According to the Ilaje tribe in Abereke, Ondo state, Nigeria, it is considered taboo to curse someone at night in their own village, and that any violation would bring ocean floods the next morning which could be very devastating for the entire community (Fabiyi and Oloukoi, 2013). When the "lawbreaker" confesses, their penalty would be to provide a fowl which would be killed and its blood poured into the river at the shrine as the initiates eat the fowl on behalf of the gods. When this is done, the flood would recede and the culprit would be pardoned. Notably, it is considered dangerous to deny an accusation by the gods, because the entire village could be wiped out. This knowledge has long helped the fishermen decide when to fish and when to prepare for devastating floods (*ibid*).

Communities in Ghana oftentimes impose fishing related taboos in order to curb the large scale withdrawal of certain fish species. For example, the Tema and Tesie communities at the Sakumo lagoon in Ghana have a taboo in place that restricts the use of draw nets and other nets of mesh size smaller than 2.5cm. The Ningo community at the Djange lagoon, also impose a taboo on the use of poles sticks and draw nets for fishing. In this way, large scale over-harvesting of fish is curbed as well as the preservation of habitats is conserved (Colding and Folke, 2001).

In Nigeria local communities that reside within the transgressive mud beach zone on the coastline, rely on their religious beliefs, culture and past experiences to deal with coastal flooding. The local population in the study area include the Ijaws, Ilajes and Itshekiri communities, while they are primarily Christian each community has different traditional religious practices and beliefs which include veneration of ancestors and respect for water spirits especially the Olokun (the god of the Atlantic). These religious practices ensure that the community members have a personal relationship with the water spirits. Prayers and good behaviour will ensure the good graces of the water spirits which in turn will ensure less flooding. Moreover, these beliefs provide a structure for communally sanctioned behaviour that ensures sustainable practices amongst community members. In addition, these communities have developed local skills and abilities that have been handed through generations to forecast for flooding and prepare for it. Through their interactions with the environment and their yearly and monthly encounters with a flood, they have noticed the significance of some indications that precede flooding in Nigerian coastal areas. These indicators are related to their capability to read the weather conditions and to their knowledge about the peculiarity of each month in their local calendar, the state of the moon, the consultation of local gods and some ecological signals (Fabiyi and Oloukoi, 2013).

Indigenous knowledge has helped farmers in OR Tambo District in the Eastern Cape in their farming practice and drought risk reduction. Farmers use indigenous knowledge to forecast droughts. The proliferation of small red ants during dry periods indicates a persistent drought (Muyambo *et al*., 2017). As a result, in the past village leaders would conduct rituals with the belief that after the ritual the rain will come. The villages in OR Tambo would announce a chief meeting where village leaders would set a date and time to go up to a sacred mountain such as Ku-Qwempe to conduct a ritual to request rain from the ancestor. In the mountain, they would perform a traditional dance known as *Imingqungqo* or *umxhentso*. People would carry along traditional beer and would slaughter one of their cattle. It is believed that it will rain after the ceremony.

American taboos, cultural, religious and spiritual beliefs

In the Andean mythology, the toad is believed to be associated with reproduction and fertility (Saylor *et al*., 2017). Furthermore, they are also used to forecast weather conditions. An increase in the number of toads is an indication that the rainy seasons is approaching (Saylor *et al*., 2017).

Religion and religious ceremonies play an important role in the way farmers recognize climatic variability. Farmers in Tlaxcala Mexico believe that "the weather is the will of God", suggesting that any scientific efforts used to forecast weather precisely would fail (Eakin, 1999). Farmers believed that if the rains were late or have stopped for some period, the community should go onto the fields and pray for better weather.

Asian taboos, cultural, religious and spiritual beliefs

In India, there are a number of sacred groves that is revered by the local populations. Culturally a sacred grove is set apart from forests for spiritual and religious purposes. These habitats are regulated by means of taboos that provide protection to all forms of vegetation. The grove is considered sacred by virtue of the fact that a deity or their spirit resides in the grove. However, some scholars (Gadgil and Vartak, 1976) argue that sacred groves are a legacy of the traditional Indian shifting cultivation system known as *jhum*. There are a number of sacred groves currently in India, amongst others: Khasi Hills (Assam), Aravalli ranges (Rajasthan), Western Ghats, Bastar and Sarguja (Madhya Pradesh) and the Chanda District (Maharashtra). With rapid deforestation in India, sacred groves provide an important source of forest products for local communities. (Gadgil and Vartak, 1976; Colding and Folke, 2001.)

In the Sariska region, India, to cut the *peepal* (sacred Fig Tree, *Ficus religiosa*) and banyan trees (*Ficus benghalensis*) is considered as heavenly offensive Spirits of the ancestors reside in those trees reflect the tie between the world of the living and the world of the dead, and a connection between the physical and philosophical dimensions (Alexander *et al*., 2016).

In Uttarakhand, central Himalayan region of India, during *Sravana* (fifth month of the Hindu calendar) a number of social groups stop consuming fish, poultry and meat (ra, 2010). Similarly, community leaders of Maluku Island in Indonesia, use customary management to ban fishing activities. These traditional methods ensure that everyone has equal access to natural resources. Moreover, traditional communities with their collective knowledge of biosphere, are exceptional observers and interpreters of change in the environment.

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European taboos, cultural, religious and spiritual beliefs

The customs and religious beliefs of the communities of North Russia, Siberia, and the Far East shaped the evolution of their traditional forest-related knowledge and practices. Animistic traditions, such as the belief that human beings, as well as animals and plants, are endowed with spirits, support the idea of mutual respect and esteem between humans and nature. Totems play an important role in nature conservation in these indigenous cultures. In the past, people of the Amur River area considered the moose, otter, wild hog, bear, tiger, and other animals as totems, and either forbade or strictly adjusted their hunting. They had similar restrictions for certain birds, snakes, frogs, and turtles, which were considered sacred. Some trees, including the birch, larch, and oak, also represented protective spirits. Additionally, the indigenous peoples' names for wildlife species display that they believed in an interaction of animals, plants, and people. The people living along the Amur River and in Sakhalin Island believe that plants have a 'soul'; therefore, one cannot break trees, or tear grass without a household purpose (Bocharnikov, 2011).

In Doñana, southwestern Spain local beliefs played a major role in institutionalized responses to environmental change. Central to the local belief system is the religious icon known as 'Our Lady of the Dew' who was declared the patron saint of Almonte village in 1653 (Gómez-Baggethun *et al*., 2012). The Virgin has been worshiped by the locals since 1280 for her believed power to protect from environmental disasters, and since the 16th century, religious ceremonies have been organized by the locals– locally known as *Venidas* or *Traslados* – to pray for her assistance in response to environmental extremes (Gómez-Baggethun *et al*., 2012). Rogation ceremonies were organized to seek help from saints to end drought periods (*pro-pluvia* ceremonies) or long wet/stormy spells (*pro-serenitate* ceremonies), which were culturally represented as divine punishments (Gómez-Baggethun *et al*., 2012). Rogation ceremonies were held in specific places of Spain, mostly between the 16th and the 19th century.

In northern Russia, the Nutendli community now educates the next generations to the nomadic lifestyle to make them more resilient to changes that modernity and now climate change are imposing on them (Hassol, 2004). Through the schools, the community is able to build a relationship to the rapid changes of their land while ensuring that their knowledge and traditional livelihoods survive.

Oceanian taboos, cultural, religious and spiritual beliefs

Indigenous people have used traditional knowledge, skills, customary laws, taxonomic systems, and traditional practices to sustainably utilize their rich natural resources as a basis for adaptation to change (Lauer and Aswani 2010).

Chiefs among the clans of Tikopia in the Solomon Islands impose sporadic taboos on the harvesting and consuming of particular resources such as yam, taro, breadfruit, and coconut. These taboos may be imposed weekly to seasonally by the Chief during a public meeting. During the taboo or closure period, coconut trees, for example, are protected during seasons where they are not bearing well. The taboo will ensure that the trees are maintained until they sprout and they can be transplanted. The taboos are enforced by the chief by declaring his totem animals such as bats and eels as informants and deterrents. The institution and enforcement of such taboos support conservation practices and resource management. (Chapman, 1985; Colding and Folke, 2001).

Among the Miriwoong, an indigenous community who reside in the township of Kununurra in the East Kimberley region of north-west Australia, the environment is positioned as sentient and communicates with the Miriwoong. It is therefore considered of great importance to listen to nature as it speaks to the elders of the community. A good example of this is the seasonal calendar that has been developed by the Miriwoong. The seasonal calendar is a physical manifestation of traditional ecological knowledge consisting of observations and adaptations to changing environmental conditions that have been collated and interpreted over many Miriwoong generations. The seasonal calendar provides essential knowledge about the ecosystem dynamics over a considerable period of time as well as its response to changes and guides their resource management and use (Leonard *et al*., 2013).

In Viti Levu (the largest island of Fiji), it is believed that if a fisherman catches a *Na Ki* (banded tail goatfish *Upeneus vittatus*), and unknowingly brings it to the village, there will be a tsunami soon afterwards (Janif *et al*., 2016).

In Covalima, Liquiça, and Viqueque, Timor Leste, killing sacred snakes (*Rainain Samea Lulik*), cutting down sacred trees (e.g., teak, bamboo, and gmelina) or removing the sacred stone (*fatuk lulik*) is forbidden, especially from river banks (Hiwasaki *et al*., 2014). If landslides occur, it is believed that such hazards were brought by people breaking these rules, and rituals to 'apologize' to nature' for the human behaviour that caused hazard – such as *Monu ain ba lulik* ('apologize to nature') – are held, in addition to reforestation of the affected area. The ceremony reinforces respect for nature and assures that villagers follow the sacred rules if not, they will get nature's curse and disasters will occur. Disasters provide an opportunity for social cohesion, respect for nature, and awe for nature. Rituals and ceremonies, along with customary laws that govern behaviour, engender and reinforce respect for the environment as well as strengthen social cohesion are conducted to enable communities to better face and respond to the impacts of climate change and other hydro-meteorological hazards (*ibid*).

In response to water shortages during long dry seasons or droughts, communities in Laco-Mesac and Ulmera (Timor-Leste) organize rituals to bring rains that are led by the elders in the sacred places (Pinto, 2014).

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TOPIC 4.3. ALTERNATIVE LIVELIHOOD STRATEGIES

Alternative livelihood strategies in Africa

In northern Burkina Faso, Sahelian community, migration seems to be one of the key strategies adopted by many farmers in times of drought, although difficult to leave their own communities, migration provides a source of income (Barbier *et al*., 2009).

In the Guba district of Benishangul Gumuz Region, Ethiopia, many households used the gathering of wild plant products as a coping strategy during a food shortage. Most people would go to the forest for a few days to gather edible fruit, leaves, and tuber, and return once they have collected enough for their families (Fentaw, 2013). Besides the feeding of wild fruits, leaves and tuber can diversify the nutrition of the households as almost all households consume a staple food of sorghum porridge. In addition to their own consumption, few people engage in the collection and selling of wild food (*ibid*). Moreover, as part of the coping strategy during a food shortage, the male from each household is responsible to hunt wild animals and take the flesh to their family. Children and women also engaged in small animal hunting like bird species and others (*ibid*).

Culturally, Guba people share the available cooked food at home with others. They prepare food in one's house with a round turn base and eat together. For instance, if today food is prepared in one individual home, all the neighbours would be invited to share the meal (Fentaw, 2013). The following day, it will be the turn of another family to prepare the meal of the neighbourhood. During trying times, families that deplete their reserves of sorghum crop will survive by eating meals cooked by other families (*ibid*). This is a form of a coping strategy implemented by many Guba people, particularly during intense climate variability.

In other instances, when communities faced short term shocks/problems they depleted productive assets by selling them to mitigate short term challenges. Furthermore, seasonal migration was one of an alternative to coping mechanisms. Many would migrate to the neighbouring country, Sudan and be employed as a daily labourer with better wage rate than in Guba. Families back home would receive remittances from the migrant until they return to their homeland (Fentaw, 2013).

In the Benishangul Gumuz Region, Ethiopia, there are few places where gold is found. According to Fentaw, (2013), some households practice traditional gold panning as a source of income to purchase food crops and other basic needs. Other coping strategies during food shortage include daily labour, charcoaling, firewood selling, water fetching for better people, etc. to earn money to buy food crops.

Fentaw, (2013), notes that "changes in farm management include a wide range of adjustments in land use and livelihood strategies that go beyond the usual agricultural practices accessible for adjusting with frequently varying biophysical and socioeconomic conditions." In the face of increasing climate variability and gradual changes in average climatic conditions, farmers may re-evaluate the crops and varieties they grow and may consider shifting from farming to raising. They may also introduce different livestock breeds that are more resistant to drought.

Around the world, many countries have changed their cropping systems due to climate variability. According to Kurukulasuriya and Mendelsohn (2006), "crop selection among African farmers differs notably in cooler, moderately warm, and hot regions." Farmers select sorghum and maize-millet in the cooler regions of Africa; maize-beans, maize-groundnut, and maize in moderately warm regions; and cowpea, cowpea-sorghum, and millet-groundnut in hot regions (Kurukulasuriya and Mendelsohn 2006). For instance, in a case study covering villages in three South African provinces; Khomele in Dzanani District Limpopo Province, Mantsie in Lehurutshe District, North West Province and eMcitsheni, in uThukela District, KwaZulu Natal, it was found that during dry spells farmers minimized their investment in crops or even stop planting and focus instead on livestock management (Thomas *et al*., 2007). As climate change scenarios forecast an increase in climate variability in many parts of Africa, farmers probably will turn to this temporary coping strategy more frequently and thus turn it into adaptation.

Furthermore, the study also found that farmers are increasingly trying to utilize the spatial diversity of their landscape. The villagers tried to gain access to land that gives good yields during times of drought

because there is a water source for irrigation reachable at plot level (Thomas *et al*., 2007). By comparing cases in the Roslagen area of Sweden and the Mbulu Highlands of Tanzania, Tengö and Belfrage (2004), established similarities in practices aimed at addressing temporary drought at field level. For instance, farmers in Sweden and Tanzania both use cover crops to improve seedling survival. On the other hand, "controlling erosion by using contour planting, mulching, and the construction of cut-off drains and sluices" was common only in the Mbulu highlands, where the fields are on a slope (Tengö and Belfrage 2004).

Though the weighting of different factors is problematic, smallholder farmers' crucial need to control the widespread risks in their livelihood system clearly is a strong driver of diversification. While commercial activities beyond subsistence agriculture often do minimize the risk of suffering as a result of climate hazards, sometimes they also have the opposite effect. Paavola (2004), reports that extreme use of natural resources in the Morogoro region, south-eastern of Tanzania sabotage sustainable land use. In the face of drought people diversify into the production of charcoal, which increases rates of deforestation, and into artisanal mining, which leads to soil erosion and water depletion (Paavola, 2004). According to Bryceson (2002), increased diversification has impacted the division of labour and decision making power within smallholder households and has caused a widening of wealth differentials between households.

Furthermore, evidence from case studies shows that local or indigenous knowledge can be beneficial or problematic in the context of climate change adaptation. Siedenburg (2008), analysed local knowledge about agroforestry practices in the context of instant environmental change in the Shinyanga Rural District of Tanzania. He found that some smallholder households do not actively foster the restoration of key farm-based natural resources, and he concluded that variations in local knowledge may be a key determinant of their use of this practice. Furthermore, his study found that Shenyang's farmers were unaware of the useful impact of trees and calls for providing them with tailored information about agroforestry and the role of trees for groundwater and soil conservation. In contrast Mbilinyi *et al*., (2005) emphasize that existing indigenous knowledge of rainwater-harvesting technologies in the Kilimanjaro region of Tanzania is a crucial asset for designing and implementing irrigation technologies in the future.

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Local networks have multiple functions in minimising vulnerability and improving adaptive capacity. According to Campbell (1999), farmers and herders of the Kenyan Kajiado District rely strongly upon social cohesion to adapt to dry drought. Many have depended on assistance from relatives or friends as a response to the severe drought. Osbahr *et al*., (2008) found that in the Gaza province of Mozambique, "traditional labour exchange mechanisms have become more popular in the last 20 years." A local practice called Kuvekala, which allows those looking after other peoples' livestock to keep the firstborn animal as payment, had become more commonplace since the late 1980s (Osbahr *et al*., 2008).

Thomas *et al*., (2007) found in their study from South Africa that collective action has emerged as an important way to enhance adaptive capacity. eMcitsheni village in Kwazulu-Natal province has developed a maize cooperative to address marketing risks and minimize production and transportation costs. In Khomele village in the Limpopo province used existing cooperative structures to search collectively for new sources of agricultural income such as small-scale horticulture, poultry, and egg schemes (Thomas *et al*. 2007).

In Central Plateau of Burkina Faso, diversification of livelihood sources, specifically in sectors that are not rainfall-dependent, is a crucial strategy for minimising household vulnerability to climate risk. Most households depend on cash income from various economic activities to purchase grain when their own production falls short. Men may practice masonry, butchery, tailoring, or bicycle repairing, for instance; while women may brew beer, sell cooked food or sauce ingredients, or make shea butter, baskets, and other items for the market. Kongoussi's lake and Bonam's reservoir also supply opportunities for fishing and dry-season production of vegetables, maize, and rice for additional income (West *et al*., 2008).

The mountains surrounding Kongoussi have gold-bearing ore deposits, which allow local households to participate in artisanal gold mining during the dry season. Because of their greater access to roads and markets, households in Kongoussi and Bonam can participate in trade, while Rollo's relative isolation restricts the opportunities for off-farm income. Nonetheless, drought and famine compromize the viability of off-farm income generation activities by minimising the provision of water and raw materials, the availability of money to invest, and the demand for products and services. (*ibid*).

In the Mantheding Community in Limpopo Province, South Africa indigenous plant resources make up an important part of the communities' livelihoods. Indigenous plant resources supply rural communities with non-timber forest products that supply energy, food, shelter, and medicine. Indigenous plant users in rural communities have established selective management processes to manage plant resources. The most common management processes are restrictions on the cutting of green plants, harvesting of some species during certain seasons, exclusive harvesting of the leaves of specific species and collection of lateral roots from medicinal plant species. Indigenous plant species are managed through selective cultural practices where the plant users gather the plant materials through observance of local management practices. Such cultural practices are crucial in the conservation of biodiversity, rare species, protected areas and ecological processes (Rankoana, 2016).

In northern Mali, many local strategies can be considered as coping mechanisms, because they are reactive to external events. In Timbuktu region, Tin Aicha and Ras El Ma communities, though women are currently applying coping strategies, they consider it crucial to develop long-term strategies, such as investing in children's education. However, because of their exclusion from decision-making and increasing workloads (particularly as a result of men's migration), opportunities are lacking (Brockhaus *et al*., 2013). Children's education was considered the most crucial strategy by women of both communities. Their long term objective is to give children new livelihood opportunities, preferably independent from natural resources. But, because of the workforce needs in the household, girls must often attend to domestic tasks and boys look after goats or sheep rather than attend school. This shows a trade-off between adjusting with current problems and adapting in the long-term (Brockhaus *et al*., 2013). Additionally, charcoal production is part of the strategies of Iklan women in the farmer community, who invest generate incomes in long-term strategies (e.g., children education) and increase their social integration. In the pastoral community, Illelan women argued that charcoal production does not match their high perceived social status, this restricts their diversification opportunities (Brockhaus *et al*., 2013).

The Dassenech and Nyangatom communities in Ethiopia, use a combination of indigenous coping strategies to help them withstand environmental change. These methods are suited for their culture and have passed on from generations to generations (Gebresenbet and Kefale, 2012). For example, during extended droughts, community members sell their livestock. Additional measures comprize, diversification of activities, such as involvement in business, casual labour for income generation, to exchange livestock against cereals and to graze the livestock beyond political boundaries during dry periods.

Moreover, changing diets with climatic situations is identified as a food security strategy. An illustration is provided through a study on communities around the South Omo River (Ethiopia) where crops and milk dominate after harvest, meat dominates in dry periods, and fish (which is a taboo during normal periods) is only eaten during periods of serious drought. Also, migration is another alternative, besides the use of migration as a flood protection strategy, pastoralist communities migrate in order to find "greener" areas for their livestock and access to water (Gebresenbet and Kefale, 2012).

During periods of drought, some communities in Northern Ghana, intensify the picking and processing of Shea nuts and *dawadawa* by local women, while the men cut grasses for sale. Shea nuts are processed into oil and soap while *dawadawa* (the seeds of Parkia biglobosa, otherwise known as the African Locust Bean Tree) is processed into oil (Yaro, 2010). At the peak of the hunger period, people rely on the use of Shea butter and the leaves of some edible plants. They boil the leaves and then add Shea butter, which enables them to adjust until the early crops are harvested (Yaro, 2010). While in the Teso region of Uganda, community folks would harvest termites and wild fruits and vegetables for food (Egeru, 2012).

As seen from the above examples, climate change is one of the biggest challenges facing humanity across Africa. Be it an increase in temperature, less rainfall, unpredictable weather changes, Ethiopia and most East African countries whose economies are mostly reliant in rainfed agriculture are particularly feeling the effects of environmental change. Their various indigenous strategies helped them to build resilience against the negative impacts of climate variability.

Pastoral and agro-pastoral communities react to environmental shocks or stressors in a number of ways. Most families within communities experience similar amount to climatic stressors, livelihood outcomes vary greatly, both within and between communities due to different access to strategies (Naess *et al*., 2010). The community of Gao and Mopti regions of Mali has adopted several livelihood strategies for the impact of environmental change. In the 1990s, the Gao community has developed "small irrigated village perimeters and construction of dykes for water management" (Naess *et al*., 2010). This strategy has positively impacted the community, in terms of having better control of the Niger River water levels, improved rice yields and agriculture residues for livestock. The main livelihood for these communities depends greatly on the climate. Without the right amount of rainfall in certain areas during the year, harvest and livestock are threatened. While all communities have similar degrees of exposure to similar climatic stressors, the impacts on livelihoods vary greatly between the different regions due to varying access to strategies.

During Harvesting, farmers of the OR Tambo District in the Eastern Cape reserve big maize cob to build round huts known as *Isiswenye* or *Intanyongo* (Muyambo *et al*. 2017). The grains stored in those huts are used as seed in the next growing season. Also, after a good harvest of maize and sorghum, farmers keep some of the harvests in big water tanks, in preparation of the drought periods. Farmers would also dig a big deep hole in the middle of the kraal (the homestead) as a means of storing excess food or production, this would prevent thieves from gaining access to the food (*ibid*).

Treepreneurs (people who make income' creation through growing indigenous trees in exchange for goods and services) Buffelsdraai reforestation project in EThekwini Municipality have been assisted by indigenous knowledge to confidently participate in the identification, harvesting, and propagation of indigenous tree seeds (Dinga *et al*., 2017). These include prior harvest preparations such as the use of other traditional medicines to safeguard one from venomous animals in the forest. These traditional medicines are referred to as "izihlungu". These traditional blends (izihlungu) are said to repel snakes, therefore the treepreneurs do not have to wear protective gear, but rather use these protective repellents that are readily available in nature. Such

repellents may include ingestible mixtures or burnt materials and even topically applied home-made solutions.

In Zimbabwe, farmers, especially women in Nyanga, Chipinge, Mudzi, Chivi and Gwanda districts, undertook many actions to mitigate drought and these resulted in at least some level of food security. The following are some of the measures employed: Permaculture; helps farmers prepare for drought through land use designs that intensify crop diversity and water conservation (Altieri and Koohafkan, 2008). Water harvesting; farmers harvest water from rooftops and divert water from natural springs into tanks. This ensures that they have a substantial amount of water stored up. In the case of a drought, the stored water will be able to sustain them for about five months depending on the volume of the tank. The water is also used for supplementary irrigation of vegetables and crops. Infiltration pits; some farmers dig infiltration pits along contours (*ibid*). Water collects in the pits during the rainy period. When the weather becomes dry, as in the case of a short period of rains, the water infiltrates underground and is used by the plants. Crops can grow up to maturity by using this conserved moisture. Farmers' experience shows that even if there are only five days with rain in the whole rainy season, the crops will reach maturity using conserved and harvested water in the pits (*ibid*).

Additionally, granaries are used by most farmers to store food to be used in case of a drought. They have a specific granary stocked with a grain (sorghum, millets, and maize for a shorter period of time), especially those resistant to post-harvest pests. Drought-tolerant crops; many farmers favour the use of traditional grains such as millets and sorghums that are more drought-resistant than maize and therefore give a good yield even with very little rain. Farmers also favour specific crop varieties for drought seasons, such as an indigenous finger millet variety (chiraufe), a cucurbit (Nyamunhororo), as it ripens fast, and early maturing cowpea (Vigna unguiculata) variety (Altieri and Koohafkan, 2008).

Alternative livelihood strategies in America

In both Mexico and Brazil, reforestation is an important management strategy that increases carbon stocks in ecosystems. Forest products provide safety nests for local communities when agricultural crops are unsuccessful as well as hydrological services such as base flow conservation, storm flow regulation and erosion control (Locatelli *et al*., 2010).

Alternative livelihood strategies in Asia

The Bisnois of the Thar Desert in India endeavour to manage their resource base through the management of a keystone process tree species, *Prosopis cineraria* which is a leguminous tree. This tree helps to fix free nitrogen and enrich the soil, and this provides ideal conditions for crops to grow under the shade of the trees. The trees also provide fodder while the branches provide fencing material and firewood while the pods are eaten by both cattle and humans. This kind of multiple species management results in soil fertility and crop protection in an otherwise hostile environment. As desertification is said to increase in some areas due to the effects of climate change, multi-species management may provide useful solutions (Berkes *et al*., 2000).

In north-east India, the maintenance of more than 40 crops in a shifting cultivation landscape of different varieties allows indigenous communities to survive through harsh weather conditions (Nakashima *et al*., 2012).

In preparation for long periods of storms, people of Rapu –Rapu Island in the Philippines preserve food by digging a hole in the ground and placing a root crop like cassava inside the hole and refilling the hole with soil. The stored root crop which has prevented rotting can last a month; thus proving food security during long periods of a storm (Hiwasaki *et al*., 2014). Root crops grow underground and this practice is a natural way of preservation.

Alternative livelihood strategies in Oceania

In south-west Kimberley, Western Australia Miriwoong people, and other Australian Aboriginal groups have developed a variety of strategies to cope with the climatic variability such as resource sharing, group mobility, fire management, and harvesting practices. Miriwoong people use management of natural resources centres on customary rules based on weather conditions and seasonal signals contained within their seasonal calendar. In Indonesia, there are regulations that serve to prohibit and mitigate hazards such as landslides, floods, and coastal abrasion, and strengthen social relations within communities (Hiwasaki *et al*., 2014).

Prior to cyclone season, Elders from Naselesele village, Taveuni Island, encourage the community to use their local knowledge to prepare for such extreme weather events (McNamara and Prasad, 2014). For example, locals are encouraged to plant kumala (sweet potato) before December so that there is always food in case of a cyclone, which can destroy staple root crops (such as taro and cassava) and fruit trees. Wild cassava can also be found in and around the plantations and is a good crop to rely on in case of food shortages.

In Kimbe, Papua New Guinean, villagers plant different crop varieties to increase chances of food availability during drought; while in Bulolo village, banana, cassava, and Taro (*Colocasia esculenta*) are used as disaster crops since they survive in floodwater. Villagers wrap the bananas in leaves to protect them from water and birds (Sithole *et al*., 2015). Taro is cultivated in drains dug in the flooded soil. In addition, cassava and bananas as a staple in times of drought. Traditionally, during dry periods, villagers in the Papua New Guinean also survive on the meat of a wild bird (Wembel) found in the grassland.

OTHER PRACTICES

Other practices in Africa

In the Guba district of Benishangul Gumuz Region, Ethiopia, women, and children are the most affected by the impacts of climate variability and change-induced hazards, as their primary role is to carry out the "routine" of household activities. The increase of environmental change has now created a further burden, thus making them even more vulnerable to the impacts (Fentaw, 2013).

In many parts of the world, persistent droughts have led to an increase in forest fires and desertification and as a result, cause scarcity of fuelwood which plays a crucial role in indigenous and traditional people's livelihoods (Macchi *et al*., 2008). Indigenous communities such as the Dayak of Borneo in Indonesia, the Baka Pygmies of South East Cameroon and Bambendzele of Congo have implemented a number of adaptation strategies, for example, when there is lack of fuel for cooking, community members minimize their intake of warm meals. However, this has had health implications, particularly because, during hot seasons, germs multiply at high rates (*ibid*). More so, a decrease in the availability of water and fuelwood have had particularly serious implications for women and children. Notably, women from these traditional communities, apart from being involved in the care of children and the elderly, are also in charge of household food production and water and firewood collection (*ibid*).

A change in climate may further increase the time necessary for completing these errands as the accessibility of water, vegetation and fuelwood may be minimized. For instance, scarcity firewood and safe water could prompt these communities to take their children, especially girls, out of school, in order to help their mothers to complete these tasks (*ibid*). Macchi *et al*., (2008), goes further to write, women from these traditional communities are expected to be particularly affected by the effects of environmental change and as such, "their unequal involvement in reproductive work, their frequently insecure property rights and availability to resources as well as of their reduced mobility due to caring for children and the elderly in situations of stress," are some of the factors aggravating their particular vulnerability (*ibid*). Indigenous women continue to be vulnerable to the effects of climate change which may often add to their already marginalized situation.

Other practices in Asia

In the Terai area of Nepal, before floods come, women take their assets and livelihoods in higher places, sometimes, even their livestock. Those who have enough resources increase the platform level of their houses or homestead to protect their belongings from damage. They also build community shelters. Women farmers also switch to cultivating crops that can be harvested before flood season. Others grow rice varieties that survive above water when the floods come. Even the seedbed preparations and seed selection are altered to ensure crop survival (De Chavez and Tauli-Corpuz, 2009).

Climate change-related food insecurity may result in especially high health risks for women as they often eat last and least, making them susceptible to illness, with more new-borns facing malnutrition (*ibid*). Longer distances and increased time for women to look for water, food, and firewood often lead to girls dropping out of school as their help is needed in their families. The loss of education has lifelong impacts and results in a lower chance of them claiming their rights. Additionally, increased violation of women's and girl's rights in the context of climatic variations have also been documented, for example, in the case of pastoralist communities trading their daughters at ages as young as eight years old in order to replace livestock loss from drought (*ibid*).

WAY FORWARD

Anthropogenic climate change is the ultimate manifestation of humans' growing disconnect with the natural world (Green and Raygorodetsky, 2010). While indigenous people living on their ancestral territories bear little responsibility for current and future projected consequences of a changing climate, both their land and resources are experiencing a vast array of climate change impacts. They indeed suffer from direct and indirect climate change due to their close connection to the natural world and their reduced socioecological resilience. Multiple social, environmental, economic, and political stressors increase the vulnerability of Indigenous peoples to climate change impacts, putting their livelihoods, communities, and deep connections to the natural and living environment at risk (Maldonado et al., 2016).

Conservation of biodiversity is an integral part of their lives and is viewed as spiritual and functional foundations for their identities and cultures. Indigenous people manage natural resources through their own customary institutions and in some cases, enhance biodiversity by transforming landscapes.

Given the historical knowledge of indigenous people to cope with the variability of the local climate, they can provide various tools and means to tackle present climate change. Henceforth, the need to strengthen the dissemination of indigenous knowledge and to integrate modern approaches that reinforce indigenous knowledge in climate change adaptation and resilience. Nevertheless, rather than encouraging indigenous knowledge systems to become more scientific, their distinctiveness and epistemology should be acknowledged. The extent and complexity of today's challenges require the mobilisation of the best available knowledge for decision making. Indigenous knowledge is local and context-specific, transmitted orally or through imitation and demonstration, adaptive to changing environments, collectivized through a shared social memory, and situated within numerous interlinked facets of people's lives (Mistry and Berardi, 2016). By virtue of their differences in temporal and spatial scale, qualitative versus quantitative nature, or holistic versus specialized character, Indigenous knowledge and contemporary science are largely complementary (UNESCO, 2017).

The listing of traditional/indigenous practices used by rural communities as coping strategies for climate change adaptation in agriculture is the first step. An agro-ecology grouping, seeking to highlight the potential of transferring practices between areas of similar agro-ecology is only the second step. There is indeed a likelihood for successful adoption of adaptation strategies from one area to another within the same ecological zone across. The third step will consist of indigenising the identified adaptation practices. Locally well adapted indigenized practices have inherent sustainability and present an opportunistic platform from which to inform new interventions in support of improved climate change adaptation strategies addressing water scarcity (Denison, and Wotshela, 2012). Indigenous or traditional knowledge should prove useful for understanding the potential of certain adaptation strategies that are cost-effective, participatory and sustainable (IPCC, 2010)

This first iteration of the compendium of practices is inevitably incomplete. Henceforth, it will benefit from the readers' comments, feedback, corrections, suggestions for further entries, and ways of improving the presentation and readability of the case studies with the view of producing an expanded and refined version.

The compendium is an important contribution to the first step above. It also provides the basis for the second step for transferring technologies and practices between areas of similar agro-ecology. In this regard, the chapter on technologies and practices with the maps in Figures 2 to 7 (together with Table 3 for Figure 5), showing the different agro-ecological zones where the six categories of technologies and practices where applied can serve a guide to test and study how the transfer is effective and accepted, taking into account other factors, beyond the similarity of the agro-ecology.

It is therefore recommended that, in the face of exacerbating climate change affecting agriculture and food security, such transfers are actively pursued and documented, even in a piloting phase. This will prepare for the third step of indigenising such practices and for their wider adoption and upscaling. It will be an important contribution of indigenous and traditional knowledge to climate change adaptation.

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